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BUREAU OF COMMERCIAL FISHERIES

REPORT OF THE BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY, GALVESTON, TEXAS

Fiscal Year 1967

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The Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex., and its field station in Miami, Fla., conduct fishery research in the Gulf of Mexico as part of the work of the Bureau's Gulf and South Atlantic Region (Region 2), which comprises the eight coastal States from North Carolina to Texas.

Office of the Regional Director, Seton H. Thompson, is in the Federal Office Building, Room 668, 144 First Avenue South, St. Petersburg, Fla. 33701.

Biological Research:

- Biological Laboratory, Beaufort, N.C.
- Radiobiological Laboratory, Beaufort, N.C.
- Biological Laboratory, Brunswick, Ga.
- Biological Laboratory, Galveston, Tex.
- Biological Laboratory, Gulf Breeze, Fla.
- Tropical Atlantic Biological Laboratory, Miami, Fla.
- Biological Laboratory, St. Petersburg Beach, Fla.
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- Exploratory Fishing and Gear Research Base, Pascagoula, Miss., auxiliary base at St. Simons Island, Ga.
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ABSTRACT

Progress of research is reported. Emphasis is on shrimp, and the research involves the fields of biology, population dynamics, ecology, and oceanography.

REPORT OF THE DIRECTOR

GENERAL

This Laboratory has five research programs--Shrimp Biology, Shrimp Dynamics, Estuarine, Experimental Biology, and Gulf Oceanography. Although seemingly different, each program is designed, either directly or indirectly, to provide information that will permit optimum use of stocks of commercial shrimp in the Gulf of Mexico. More specifically, our research is designed to define the entire life histories of the species; to determine the response of the species to fishing and to their environment; and to describe in time and space the environmental variations.

Each of the five programs has a number of individual projects. Progress made in these projects during fiscal year 1967 constitutes the bulk of this report, but I summarized here some of the highlights of our research.

The refining of our techniques for rearing larval shrimp spawned in the laboratory enabled us to culture successfully tens of thousands of postlarvae. Our major problem has been to grow algal foods in quantities sufficient to sustain larval growth and survival. In one rearing experiment, however, enough postlarval white shrimp were reared to stock one of the experimental ponds in which we are studying the feasibility of rearing shrimp under seminatural conditions.

After being placed in the experimental pond, the shrimp grew rapidly for 35 days, but then growth virtually ceased. When the shrimp were harvested, 84 percent of the original stock had survived and the projected yield of whole shrimp was 575 pounds per acre (645 kg. per hectare).

A major breakthrough toward management of a fishery was realized from mark-recapture studies on the pink shrimp of the Tortugas grounds. From these studies, we determined that natural mortality was considerably lower than had been previously reported. Of even greater significance, we also determined the optimum size at which to begin fishing for pink shrimp on the Tortugas grounds. The success of these studies has led to renewed efforts to establish similar criteria for the brown and white shrimp fisheries.

Although the importance of estuaries as nursery grounds for many commercial marine species is well documented, modification of these waters along the Gulf coast by residential, industrial, and agricultural expansion is increasing at a tremendous rate. Our ecological studies in Galveston Bay have shown that the shore and submerged plants, particularly in shallow water, provide nursery habitats for the young of shrimp and other species. Destruction of these plants, by whatever means, makes the estuaries useless as nursery grounds.

Field observations on the occurrence of white, brown, and pink shrimps indicate that environmental factors affect the distribution of the species. The extreme conditions of tolerance by the three species were, however, unknown. In the laboratory, tests made under controlled conditions showed that the ability of shrimp to tolerate extremes of temperature and salinity varied with the species and age (or size) of the shrimp.

We completed oceanographic cruises throughout the Gulf, during which bottom samples and hydrographic measurements were obtained. The data from these cruises are being analyzed and interpreted to discover the oceanic environmental factors that cause fluctuations in populations of shrimp as well as other commercial species of fish and shellfish. A bottom water mass, probably of Antarctic origin and not previously reported in the Gulf, was identified from hydrographic data collected during the first "All-Gulf" cruise made in February-March 1967.

Of particular interest to fisheries were the evaluations made at this Laboratory of photographs taken during the Gemini space flights. We determined from these photographs that a major advance in fishery science can come from a sound ocean-space research effort.

LABORATORY FACILITIES

The expanded activities and the increased personnel in the Director's Office made several physical changes necessary. The Conference Room, Director's Office, and Assistant Director's Office were relocated and refurbished. The south porch of one building was enclosed to provide additional laboratory space, and laboratory furniture was installed. A second structure and about 0.8 acre of land adjacent to the Laboratory complex were acquired from General Services Administration under a lease agreement for the expanded Space Oceanography Project.

A replacement tank truck (2,500-gallon capacity) was acquired to transport sea water from the East Lagoon to our recirculating sea-water laboratory.

PUBLIC RELATIONS

Nearly one thousand visitors were given Laboratory tours or taken on field trips, or both. Of 800 students and instructors, 360 were from 10 universities, 163 were from 6 high schools, and 277 were from 6 grade schools.

Other public relations activities included consultations with foreign visitors and trainees, lectures to student and civic groups, and cooperation with universities.

Foreign Visitors

During the year the Laboratory had 49 visitors from 8 foreign countries. On September 9, five Mexicans visited the Galveston Laboratory to discuss anticipated problems of disposal of waste material from a phosphate plant to be built at Coatzacoalcoa (Puerto Mexico), Veracruz, Mexico. The group included: Dilio Fuentes, Direccion General de Pesca SIC, Campeche; Cesar Mendoza Trejo, Direccion General de Pesca, Mexico, D. F.; Luis Galvez and Hector Lopez, Direccion General de Obras Maritimas, Mexico, D. F.; and Ing. Gmo. Cabrera, Fertilizantes Fosfatados Mexicanos, Mexico, D. F. Another group from the Technological Institute, Monterrey, Mexico, included: Loustaunau Javier, Jose I. Flores Ugarte, Luis A. Coutte, Manuel Robles, Ezequiel Montemayor, Sergio Flores Cavazos, and Daniel Barrera. Also visiting were: Gmo. Chavez Salcedo, Hector Romero, and Victor Martinez from the Estacion de Biologia Marina, Veracruz, Mexico. Other foreign visitors were: H. Schaefer, Monterey Institute of Technology, Monterey, Mexico; E. L. Bousfield from the National Museum of Canada, Ottawa, Ontario, Canada; Antonio Cortés, Empacadora Escuinapa, Escuinapa, Sinaloa, Mexico; G. C. Phillips, Unilever Research Laboratory, Aberdeen, Scotland; Amine Keyvanfar, Southern Fisheries Company, Tehran, Iran; Klaus Tiews, Assistant Director of the Institute for Coastal and Inshore Fisheries, Federal Research Laboratory, Hamburg, Germany; and Arthur C. Simpson, Ministry of Agriculture Fisheries and Food, Fisheries Laboratory, Burnham on Crouch, Essex, England. On June 22, 1967, this Laboratory was host to 17 scientists from Brazil and 8 from Mexico. The schedule of events included talks by R. E. Stevenson, Assistant Laboratory Director; Dale F. Leipper and James Arnold, Texas A&M University, College Station, Tex.; A. G. Alexiou, U.S. Naval Oceanographic Office, Washington, D.C.; and H. R. Bullis, Jr., Director, Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, Pascagoula, Miss.

Foreign Trainees

The Laboratory had two trainees: C. S. Subrahmanyam, a student from India, and Victor Fernando Carrillo Martinez, Estacion de Biologia Marina, Veracruz, Mexico.

Laboratory Activities

Seven staff members discussed the Laboratory's role in fisheries before school and civic groups.

The Laboratory Director was invited by committee members of the University of Texas Medical Branch in Galveston to participate in the submission of a proposal from the University of Texas to the U.S. Public Health Service for development of a medically oriented Marine Biological Institute in Galveston.

The Laboratory Director has been invited to serve, with Lyle St. Amant, Gordon Gunter, and Robert Ingle, on a committee to select a university to administer a grant for a graduate fellowship being established by the American Shrimp Canners Association.

During the year, a contract was negotiated with the Lunar Receiving Laboratory of the National Aeronautics and Space Administration. We will supervise and train personnel as well as provide facilities for receiving and holding invertebrate animals used in their experiments.

After the acquisition of the R/V Geronimo in the latter half of fiscal year 1966, we made several cruises to various portions of the Gulf to collect oceanographic data. In addition, the Graduate Research Center of the Southwest, Dallas, Tex., chartered the vessel to undertake a normal refraction seismic exploration survey along the Texas shelf and slope.

On two occasions during the year, the Laboratory Director served as an Adviser with a U.S. delegation sent to confer with delegates of foreign countries. In Honduras, the U.S. shrimp fishery off the Caribbean coast of that country was discussed; in Mexico, negotiations for a shrimp fishery treaty were undertaken.

Colored photographs of the earth's water masses taken from earth-orbiting spacecraft show features that interest meteorologists and oceanographers, among others. The Assistant Laboratory Director has studied many such photographs and gave 23 illustrated lectures during the year. Emphasis was on oceanographic features which heretofore have not been seen in their entirety and knowledge of which may have substantial impact on the fisheries of several countries.

Between June 12 and 24, FAO (Food and Agricultural Organization of the United Nations) sponsored the World Conference on the Biology and Culture of Shrimps and Prawns in Mexico City, Mexico. The Laboratory was represented by nine staff members, and nine manuscripts were presented. In addition, the Laboratory Director served as convenor for the section on "Resource Appraisal."

LIBRARY

At the close of fiscal year 1967 the library collection had about 26,400 items. Included in the additions for the year were 303 volumes of books and bound journals and 2,679 reprints and miscellaneous publications.

The increase in circulation of library materials and in reference services emphasizes the trend of growth established during the last few years. Other than the Laboratory staff, the library serves the faculty and students of Texas A&M Marine Laboratory, other educational institutions, industrial organizations, and individuals.

In addition to current activities, special projects accomplished during the year include completion of the reclassification of the book collection, the current inventory, and revision of selected indexes. Work on new indexes was continued. A weekly list of library acquisitions was distributed to the Laboratory staff and selected laboratories.

A statistical summary of the library collection for fiscal year 1967 is given in table 1.

Table 1.--Statistical summary of library collection, 1966-67

Item	On hand 1966	Additions 1967	On hand June 30, 1967
Books	2,837	271	3,108
Journals (bound)	685	32	717
Journals (Unbound)	1,823	253	2,076
Reprints	3,636	366	4,002
Publications from State and Foreign offices, etc.	12,902	1,912	14,814
Other	1,518	148	1,666
Total items	23,401	2,982	26,383

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1966. The Texas Basins Project. Amer. Fish. Soc. Spec. Publ. 3: 83-92.

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1966. The role of estuaries in the development and perpetuation of commercial shrimp resources. Amer. Fish. Soc. Spec. Publ. 3: 16-36.

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1966. What we know about shrimp size and the Tortugas fishery. Proc. Gulf Caribbean Fish. Inst., 18th Annu. Sess., pp. 18-25.

Marvin, Kenneth T., and Raphael R. Proctor, Jr.
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1967. Counts of larval penaeid shrimp and oceanographic data from the Tortugas Shelf, Florida, 1962-64. U.S. Fish Wildl. Serv., Data Rep. 16, 40 pp. on 1 microfiche. [Research under Bureau contract.]

Trent, W. Lee.
1967. Attachment of hydrofoils to otter boards for taking surface samples of juvenile fish and shrimp. Chesapeake Sci. 8(2): 130-131.

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Aldrich, David V., Carl E. Wood, and Kenneth N. Baxter.
A behavioral comparison of postlarval Penaeus aztecus and P. setiferus, with regard to burrowing as a response to reduced temperature. Bull. Mar. Sci. (21 MS. pp., 3 figs.).

Knight, Charles E., and Richard J. Berry.
Recovery data for marked pink shrimp, Penaeus duorarum Burkenroad, released on the Florida Tortugas grounds in 1965. U.S. Fish Wildl. Serv., Data Rep. (83 MS. pp., 1 fig.).

Mock, Cornelius R.
Natural and altered estuarine habitats of penaeid shrimp. Proc. Gulf Caribbean Fish. Inst., 19th Annu. Sess. (19 MS. pp., 5 figs.).

Moore, Donald.
Nomenclature of the spotted triggerfish of the eastern Atlantic Balistes punctatus. Copeia (8 MS. pp., 4 figs.).
Triggerfishes (Balistidae) of the western Atlantic. Bull. Mar. Sci. (51 MS. pp., 9 figs.).

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Seasonal distribution and relative abundance of planktonic-stage Penaeus spp. shrimp in the northwestern Gulf of Mexico, 1961. U.S. Fish Wildl. Serv., Fish. Bull. (28 MS. pp., 10 figs.).

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Stevenson, Robert E., and Dale F. Leipper.
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Data report on juvenile stages of pink shrimp (Penaeus duorarum) and on fishes collected in Buttonwood Canal, Florida, December 1962 to June 1965. U.S. Fish Wildl. Serv., Data Rep. (25 MS. pp.). [Research under Bureau contract.]

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An appraisal of the effects of salinity and temperature on growth and survival of postlarval penaeids. Proc. FAO World Conf. Biol. Cult. Shrimps Prawns (20 MS. pp., 5 figs.).

SHRIMP BIOLOGY PROGRAM

Research in this program varied from field studies to determine whether postlarval brown shrimp overwinter in the Gulf of Mexico to laboratory studies designed to develop methods for raising large quantities of diatoms to feed mass cultures of larval shrimp. More specifically, the research consisted of studying: (1) the distribution and abundance of larval shrimp in the Gulf of Mexico; (2) methods for identifying and culturing shrimp larvae as well as the culturing of diatoms for feeding larval shrimp; (3) cultivation of shrimp in artificial ponds; (4) organisms ecologically associated with shrimp; and (5) the ecology of pink shrimp in Florida Bay.

Also, personnel at the Institute of Marine Sciences, University of Miami, under contract with the Bureau of Commercial Fisheries, studied the movements of postlarval and juvenile pink shrimp into and out of the Everglades National Park estuary. Whether in Texas or Florida, our endeavors, although diversified, were designed to provide a better understanding of the life histories of shrimp in the Gulf of Mexico.

Biologists in this program were authors or coauthors of 12 scientific reports, published or submitted for publication, on various phases of the life history of shrimp. These articles, submitted to various scientific journals and serials, should be available to researchers and industry within a year.

The annual progress report of each project follows.

Robert F. Temple, Program Leader

DISTRIBUTION AND ABUNDANCE OF LARVAE

All plankton samples collected in 1964 were examined in the laboratory during fiscal year 1967. We collected the samples with Gulf V plankton nets along transects perpendicular to the coasts of Louisiana and Texas. Station depths at which samples were taken ranged from 7 to 110 m. (4-60 fathoms). Since 1962, sampling in these waters has included 1,568 metered hauls. Examination of the catches has provided information on the relative abundance and seasonal distribution of planktonic-stage penaeid shrimp. Grouped by depth zones, the numbers of samples taken in 1962-64 in Texas and Louisiana waters are presented in table 2.

Table 2.--Number of Gulf V plankton tows, by depth zones, taken in Louisiana and Texas waters, 1962-64

Depth zone and area	1962	1963	1964	Total
	Number	Number	Number	Number
7-13 meters:				
Texas	55	87	92	234
Louisiana[1]	49	88	92	229
27-64 meters:				
Texas	157	82	94	333
Louisiana[1]	171	96	88	355
73-110 meters:				
Texas	99	44	48	191
Louisiana[1]	109	59	58	226
Total	640	456	472	1,568

[1] Mississippi River to Texas.

Planktonic stages of five known genera of penaeids--Penaeus, Sicyonia, Trachypeneus, Solenocera, and Parapenaeus--were taken in plankton hauls. The data have been analyzed, however, only for the commercial shrimps of the genus Penaeus.

Seasonal Trends in Abundance

Seasonal trends in the abundance of Penaeus spp. larvae (postlarvae excluded) in 1962-64 were similar in Louisiana and Texas (fig. 1). Differences did exist between depths, however. Catches in 7 to 13 m. (4-7 fathoms) of water were restricted to April-October; the yearly trend was more unimodal here than at deeper depths, where a definite bimodal trend was evident. Catches of larvae at 27 m. (15 fathoms) or deeper, in general, increased in the spring from the winter low, decreased in the summer, and were maximum in the fall. The only exceptions were in Texas in 1963 and 1964, where catches at 27 to 64 m. (15 to 35 fathoms) in the spring approximated those made in the fall.

Overwintering of Postlarval Brown Shrimp

Because of the bathymetric distribution of adult white and brown shrimp, we believe that larval abundance trends in 7 to 13 m. (4-7 fathoms) of water (fig. 1) reflect spawning of white shrimp, and those in deeper water the spawning of brown shrimp. Such an assumption creates a problem, however, for the movement of most postlarval brown shrimp into the Galveston Bay nursery area in January-April is well documented. The period of time between the high catches of larvae offshore in the fall and the large catches of immigrating postlarvae through Galveston Pass is unaccounted for unless the development of larvae is retarded offshore, or larvae overwinter offshore, or both.

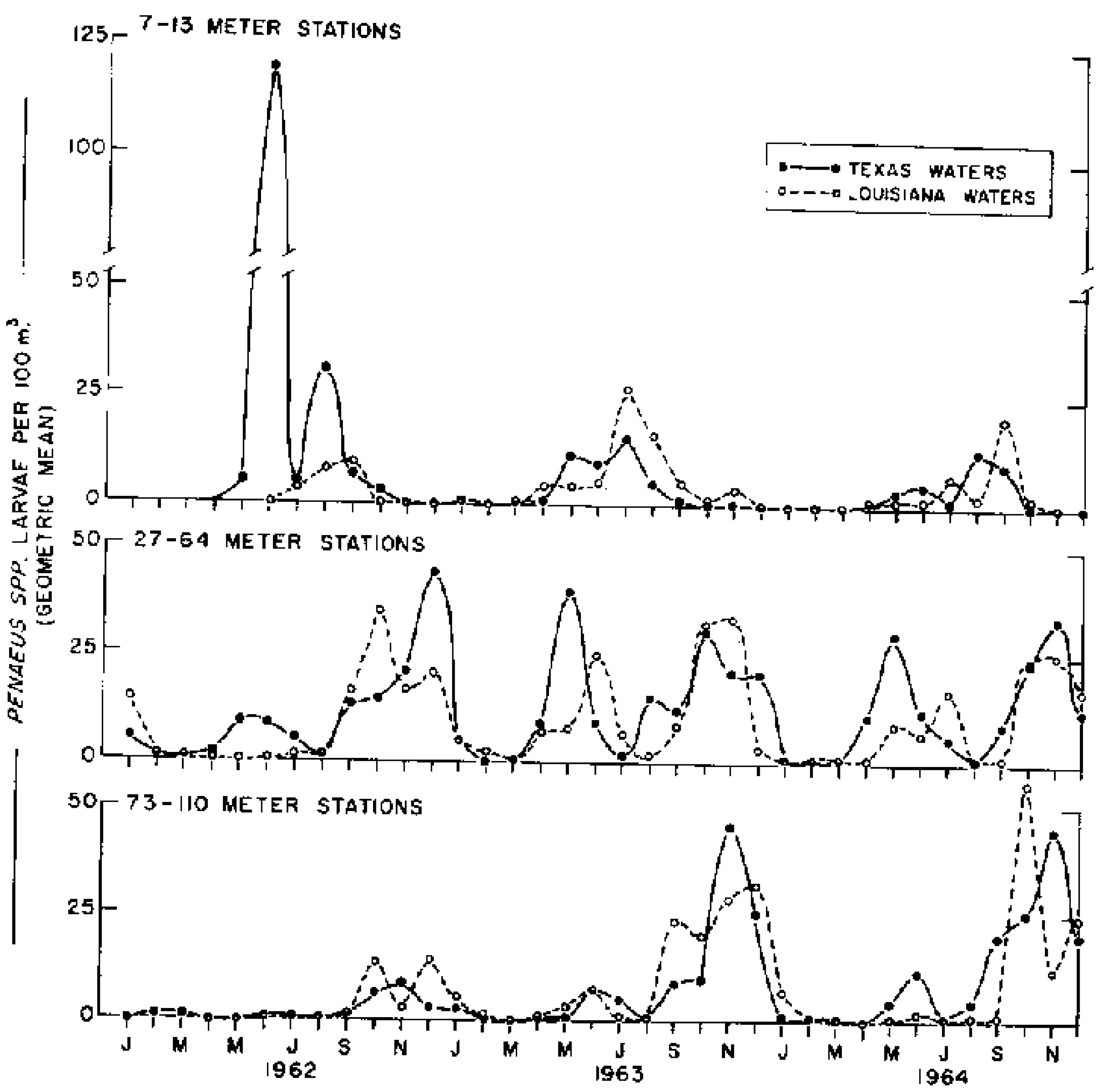


Figure 1.--Abundance of Penaeus larvae by depth zones in Louisiana and Texas waters, 1962-64.

To investigate the possibility of postlarvae overwintering offshore, we made cruises off Galveston between September and April to waters between the surf zone and to a depth of 12 m. (6-7 fathoms). Samples were taken on bottom with a specially constructed sled and in the water column with Clarke-Bumpus and half-meter nets. Postlarval brown shrimp increased in numbers from October to March in a narrow zone of water along the coast before they entered the estuary (table 3).

Table 3.--Catches of postlarval brown shrimp per 1,000 m.³ (35,000 cubic feet) of water filtered, by month and depth zone, September 1966 to April 1967

Depth range	Month							
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Meters	No.	No.	No.	No.	No.	No.	No.	No.
0.0- 3.0	46	16	122	212	12	1,032	1,085	55
3.3- 6.0	188	7	0	57	70	760	1,334	11
6.3- 9.0	157	0	0	27	17	81	143	2
9.3-12.0	0	0	0	9	0	2	7	3
Total	391	23	122	305	99	1,875	2,569	71

Personnel of the Shrimp Dynamics Program, who sampled immigrating postlarvae in Galveston Pass, made their greatest catches in February and March. These large catches coincided with ours along the coast, and the decrease in catch in April was apparent in both locations.

Monthly length-frequency distributions of the postlarval shrimp taken in our tows show a general increase in size from September to December but no increase thereafter (fig. 2). The significance of this finding is important only when considered with existing water temperatures and the documented effects of temperature on shrimp growth. In the study area, bottom water temperatures averaged about 28.0° C. (82.4° F.) in September but decreased to 15.5° C. (59.9° F.) in December. During December-March, they ranged between 11.8° C. (53.2° F.) and 15.5° C. (59.9° F.)--temperatures which have been shown by Zein-Eldin and Aldrich[1] to arrest postlarval shrimp growth. The apparent increase in numbers of postlarvae along the beach in the winter months and their retarded growth

[1]Zein-Eldin, Zoula P., and David V. Aldrich. 1965. Growth and survival of postlarval Penaeus aztecus under controlled conditions of temperature and salinity. Biol. Bull. (Woods Hole) 129(1): 199-216.

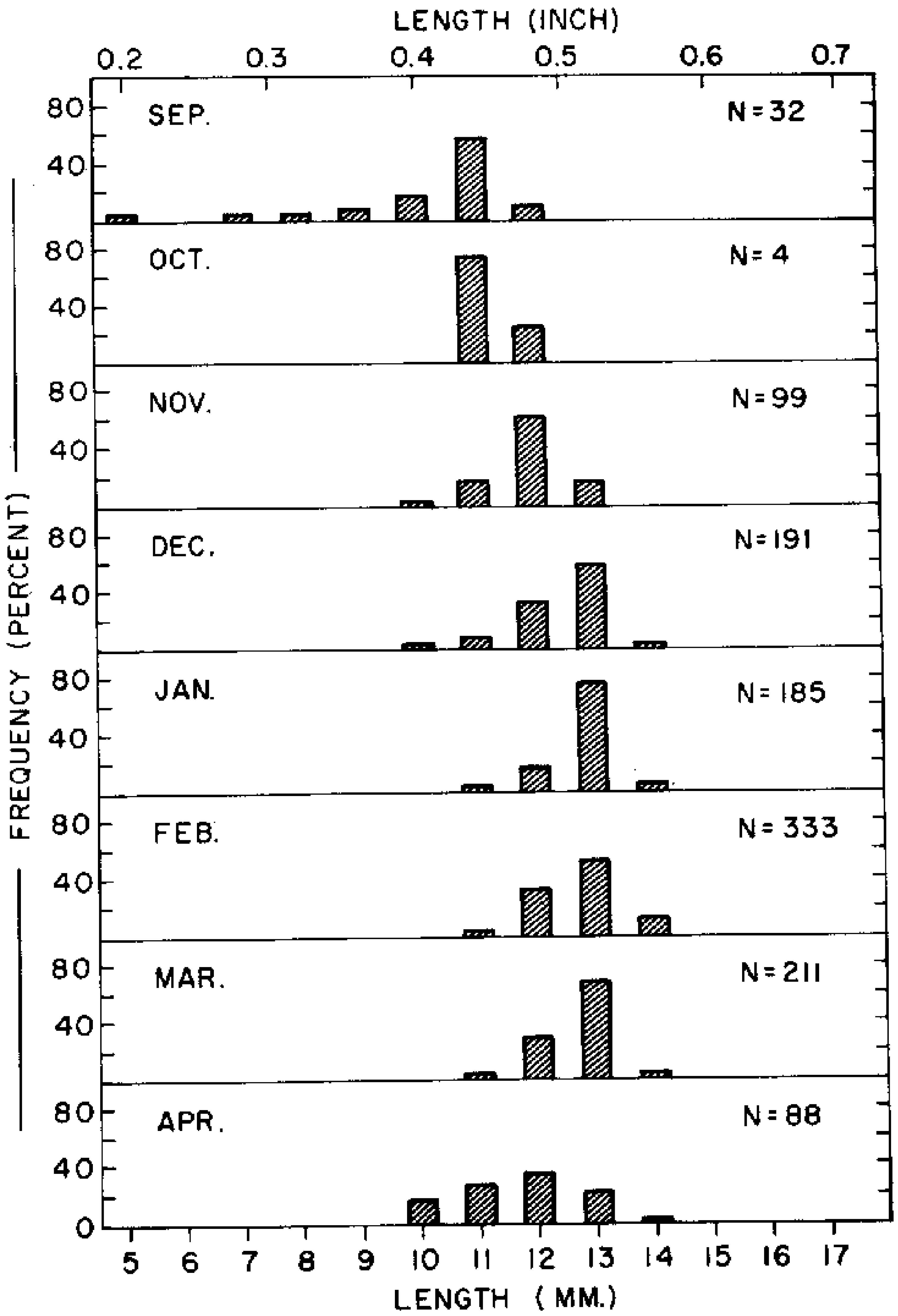


Figure 2.--Length-frequency distribution of postlarval brown shrimp, September 1966 to April 1967.

indicate, therefore, that brown shrimp postlarvae do overwinter.

Robert F. Temple, Project Leader

TAXONOMY AND CULTURE OF SHRIMP LARVAE

We directed most of our efforts during the year toward growing mass cultures of food for penaeid larvae. Each successive rearing experiment resulted in increased numbers of postlarvae; 24,000 postlarvae were obtained in the latest rearing trial. A study also was made to determine how varying light intensities affect larval behavior.

Changes made in larval culture procedures were to increase the amount of aeration and the supply of food. Aeration was supplied by airstones suspended near the sides of the tank as well as in the center. This added aeration improves water circulation in the tank, which in turn, keeps the algal food in suspension. During the protozoeal stages, we are now adding 1 liter (1.1 quarts) of diatom culture to every 15 liters (4.2 gallons) of water in the larval culture tank (fig. 3).

Larval Food Studies

It appears that the largest problem remaining for large-scale larval culture is that of supplying increasing volumes of diatoms as larval shrimp food. Last year, to solve this problem, a series of diatom cultures were started to determine if mass cultures of diatoms could be grown in water from the Laboratory's recirculating sea-water system by adding selected nutrients. Additions of NO_3, PO_4, EDTA (ethylenediaminetetraacetate), Fe, and a trace metal mixture were used singly and in combination. The addition of nutrients increased the yield over that obtained in unenriched water from the sea-water system without exception; we were able to maintain open 30-liter (8.4-gallon) cultures of both Skeletonema costatum and Thalassiosira sp.

The additive supporting the best growth of each diatom differed in different months (table 4). No single additive gave consistently better growth, but the combination of nitrate, phosphate, and EDTA most often supported the best growth of Skeletonema. Both diatoms grew well on the same additives only in September. One peculiarity was that in months when Skeletonema required trace metals, Thalassiosira did not; and when Thalassiosira required them, Skeletonema did not. Nevertheless, although both diatoms required different additives to sustain highest growth, monthly fluctuations in their growth were similar. In January and February, the unenriched sea water supported better growth than was obtained throughout the rest of the year, even with the best additives. Results from these experiments suggest that some unknown factor(s) is affecting the growth of both diatoms differently and to a greater extent than the additives being tested.

Skeletonema usually reached peak numbers in 4 to 5 days; Thalassiosira required 6 or 7 days.

Responses of Larvae to Varying Light Intensities

To determine the effects of light on larval shrimp behavior, brown shrimp larvae and postlarvae were placed in a 10-cm. (4-inch) square plastic column 137 cm. (54 inches) high and were exposed to gradually increasing light intensities (from 3 to 960 ft.-c.). Nauplii responded photopositively to low light intensities and photonegatively to higher intensities. The attraction to low intensities became less pronounced as development progressed; third myses and postlarvae were not attracted to low intensities. The design of the experiment did not allow us to determine whether the later stages were photonegative or just remaining on, or near, the bottom in response to gravity or some other factor.

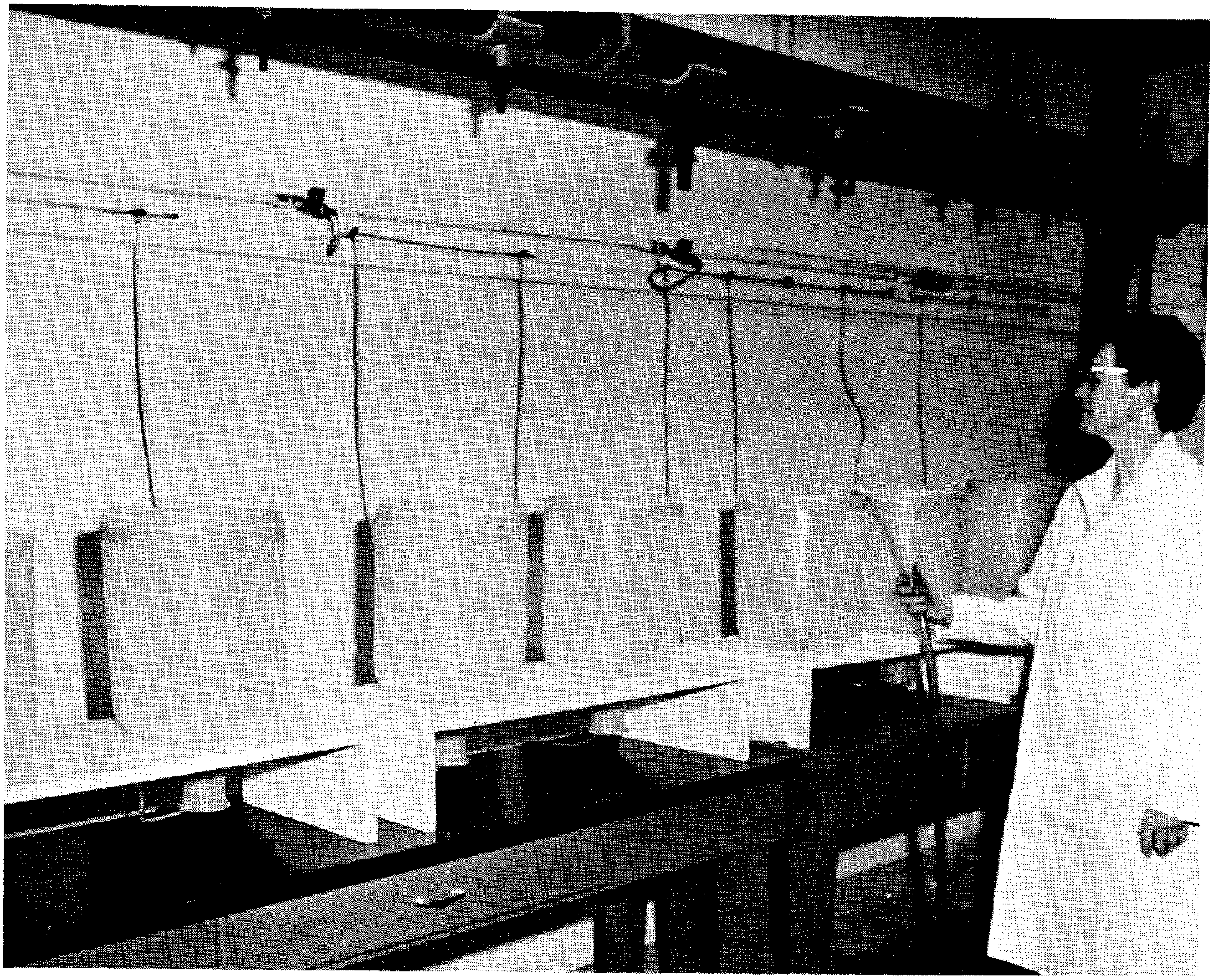


Figure 3.--Containers used to culture shrimp larvae for experimental studies.

Table 4.--Nutrients which sustained the highest growth of diatoms each month, 1966-67

Month	Skeletonema costatum	Thalassiosira sp.
April	NP+EDTA[1]	--[2]
May	EDTA	NP+EDTA+TM
June	NP+EDTA	NP+EDTA+TM+Fe[3]
July.........	NP	NP+EDTA+TM+Fe
September ..	NP+EDTA	NP+EDTA
December...	NP+EDTA+TM+Fe	EDTA+Fe
January	NP+TM	EDTA+Fe
February....	NP+EDTA+TM	NP
March	NP+EDTA+Fe	NP+TM+Fe
April........	NP+EDTA	NP+EDTA+TM+Fe
May.........	EDTA+TM	EDTA+Fe

1/ NP = KNO_3 and Na_2PO_4; TM = trace metal mixture.
2/ -- = no data.
3/ Fe = $FeNH_3(SO_4)_2$.

Light response was an individual matter in all stages. At a given intensity, some larvae were attracted toward the light and others were not. As intensity increased, the larvae did not move away en masse; a few responded to each increase until finally all were repelled.

During this experiment, we recorded the rate of movement of selected larval stages toward a low-intensity light source (table 5). The rate of movement of myses was not measured because they did not swim directly toward the light source as did the nauplii and protozoeae.

Harry L. Cook, Project Leader

CULTIVATION OF SHRIMP IN ARTIFICIAL PONDS

We used white shrimp in our brackish-water, pond culture studies during the summer of 1966. Postlarval shrimp were obtained from stock spawned and reared through the larval

Table 5.--Rate of movement of selected larval stages of brown shrimp toward a low-intensity light source

Larval stage	Rate of movement	
	Cm. /min.	Inches/min.
Nauplius II	2.3	0.9
Nauplius V	6.2	2.4
Protozoea I	14.0	5.5
Protozoea II	30.0	11.8
Protozoea III	60.0	23.6

stages in our Laboratory rather than from collections made in Galveston Pass as in 1965. Advantages derived from using laboratory-reared stock were: (1) the identity of the species was known and only a single species was involved; (2) the work of making field collections and sorting young shrimp from other organisms was eliminated; (3) the risk of introducing predatory species was eliminated; and (4) spawning date was regulated so that shrimp were available for stocking in the quantities desired at the time they were needed. We stocked white shrimp rather than brown shrimp (used in 1965) so that we could compare growth between species and rearing methods.

A single 0.05-hectare (1/8-acre) pond, fertilized with 1 cubic yard of chicken manure deposited in a single location, was stocked with 4,092 postlarval shrimp in July.

During the 121-day study, shrimp growth was initially rapid but decreased toward the end of the experiment (fig. 4). Over the entire period, shrimp grew at an average daily rate of 0.93 mm. (0.037 inch) in length and 0.078 g. (0.003 ounce) in weight, and attained an average size count of 74 tails per pound. In

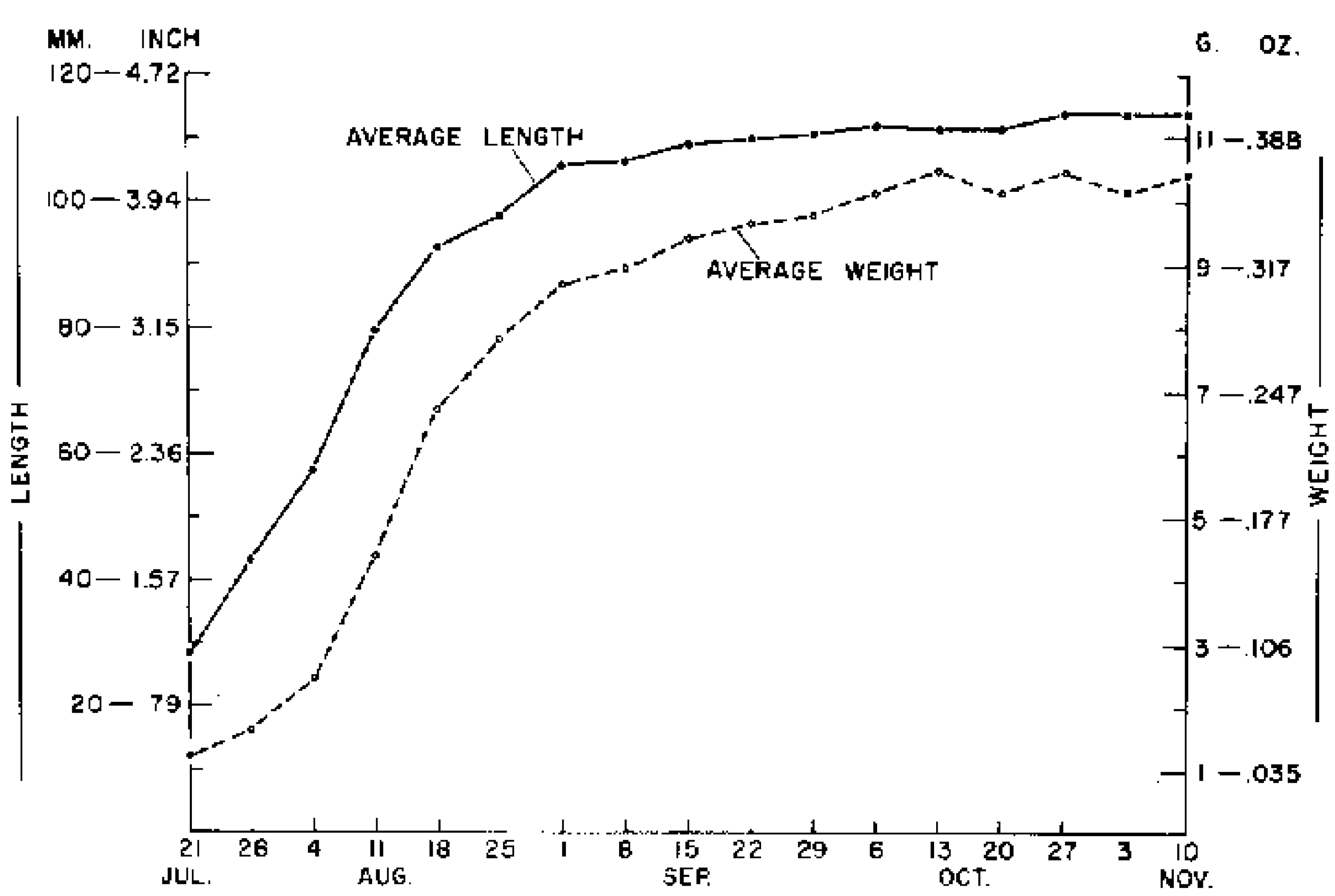


Figure 4.--Growth of white shrimp expressed as average lengths and weights over a 4-month period (July 21 to November 10) in a 0.5-hectare (1/8-acre) rearing pond to which chicken fertilizer was added.

November, 3,439 shrimp weighing 32.7 kg. (72 pounds) were harvested. The projected yield was 645 kg. per hectare (575 pounds per acre). Survival rate from date of stocking was 84 percent.

Population Estimates

At the time of harvesting, a mark-recapture experiment was made to determine the intensity of sampling necessary to arrive at an accurate estimate of the population density. A total of 328 shrimp was taken from the pond, injected with fast green FCF stain, and returned to the pond. Population estimates, based on the number of stained and unstained shrimp captured, were made after each of the 27 successive seine hauls required to remove all shrimp from the pond. More than one-half of the population was accounted for before a population estimation accuracy of 90 percent or greater was sustained.

Overwintering Studies

Overwintering tests in which white and brown shrimp were held in the same pond indicated that the white shrimp were not as hardy as the brown shrimp. The difference in average size of the two species at the time of the experiment was marked, however; the white shrimp averaged 120 mm. (4.7 inches) in total length and the brown shrimp, 18 mm. (0.7 inch). All of the white shrimp died after a series of cold fronts in January during which water temperatures dropped to 5° C. (41.0° F.) on three occasions. Most brown shrimp survived but did not grow at water temperatures below 15° C. (59.0° F.).

Present Activities

Both 0.05-hectare (1/8-acre) ponds are now being used for growth studies. In the spring of 1967, rice husks were distributed in one pond to increase the surface area of the substrate to increase the growth of micro-organisms and to fertilize the pond water inexpensively; the second pond is being used as a control.

To improve our understanding of the food chain as related to shrimp growth in our ponds, we examined water chemistry, density of particulate matter, and densities and composition of plankton communities in the water column and in the bottom sediments, in January to June 1967.

In April 1967, we stocked each pond with 9,000 postlarval brown shrimp which had been reared in the laboratory. Average daily growth of shrimp in both ponds was about 1.34 mm. (0.053 inch) in length and 0.075 g. (0.003 ounce) in weight during the first 2-1/2 months of the experiment.

Ray S. Wheeler, Project Leader

ECOLOGICALLY ASSOCIATED ORGANISMS

Our efforts during the year have been devoted to completing food studies, describing the benthic fauna off Galveston, Tex., and assisting in starting a plankton study of the Gulf of Mexico which will be continued in the future by the Gulf Oceanography Program.

Food Studies

Samples for studies of the food of brown shrimp were collected from January 1966 to January 1967. Subsamples of brown shrimp were drawn from catches made at night in 12.7 to 63.6 m. (7 to 35 fathoms) of water off Galveston and Freeport, Tex.

The average amount of food, by percentage of stomach capacity, was similar in males and females (fig. 5). Throughout the year, identifiable contents were predominantly the remains of squid and crustaceans. Occasionally, starfish (echinoderms), nematodes, and fish parts also were observed.

The food of four species of fish inhabiting the brown shrimp grounds off Galveston Island were studied through the summer of 1966. In the spring and summer, crustaceans were dominant food items of the Atlantic croaker, Micropogon undulatus; silver seatrout, Cynoscion nothus; and shoal flounder, Syacium gunteri. Mollusks and polychaete worms dominated the food items identified in the longspine porgy, Stenotomus caprinus.

Bottom Fauna Survey

Our survey of bottom fauna off Galveston Island was the most intensive ever made in this area. Samples were taken at stations in depths from 5.4 to 36.3 m. (3-20 fathoms). All specimens taken have been sorted to the major taxonomic groups. On the basis of preliminary identification of the mollusks, the samples included about 16 species that have not been previously reported from this area. Researchers at Texas A&M University, the U.S. National Museum, and the Canadian National Museum are studying many of the mollusks and amphipods from these collections.

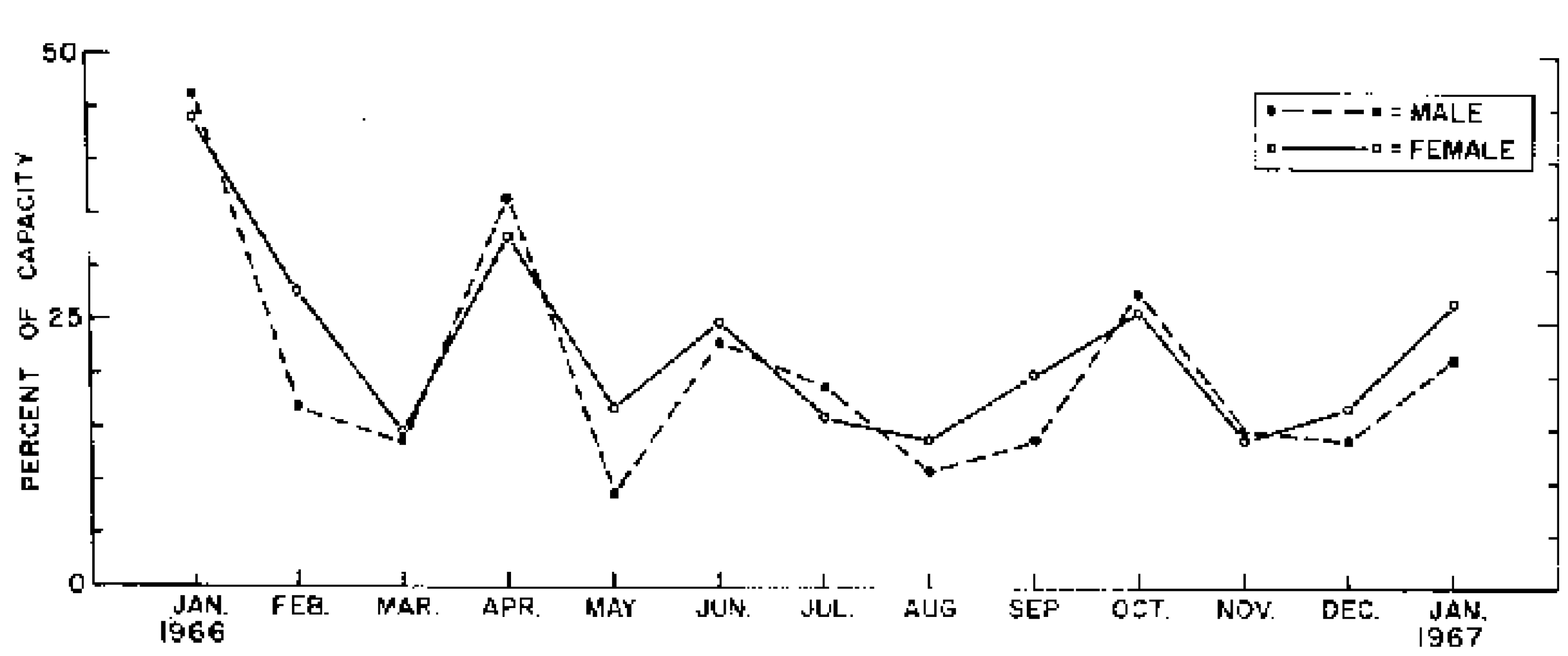


Figure 5.--Relative abundance of stomach contents in male and female brown shrimp, 1966-67.

Plankton Study

During February and March, we made a plankton survey to compare the productivity of the waters in various parts of the Gulf of Mexico. Plankton samples were collected at 87 locations throughout the Gulf. These samples were taken from the upper 100 m. (55 fathoms) of water with a vertically towed cone-shaped (Hensen) net with a 3/4-m. (2.5-foot) diameter opening.

Plankton volumes, measured in cubic centimeters per 100 $m.^3$ (3,534 cubic feet) of water filtered, are shown in figure 6 to delineate areas of high and low concentrations. Greatest volumes were collected in the western Gulf, over and just beyond the Continental Shelf south of the Texas coast. Volumes were generally greater in the northwestern Gulf than in the southwestern Gulf. In the eastern Gulf, plankton was sparse over the relatively deep waters in the Yucatan Channel and the Florida Straits.

Donald Moore, Project Leader

FLORIDA BAY ECOLOGY STUDIES

The shallow waters of Florida Bay and the Florida Keys are important nursery grounds for pink shrimp of the Tortugas grounds. Since 1965, we have made biological observations on postlarval and early juvenile pink shrimp in these extensive estuaries.

Postlarvae are sampled quantitatively once each month on incoming night tides at Whale Harbor Bridge near Islamorada (upper Florida Keys). As part of a cooperative plan similar observations are taken at three additional sites in the lower Keys by biologists of the Florida State Board of Conservation. This work has established that large numbers of postlarval shrimp enter Florida Bay from the Atlantic Ocean and that recruitment continues throughout the year. Most postlarvae pass through the Keys into Florida Bay in late spring, summer, and early fall (fig. 7).

We expanded the sampling of juvenile shrimp in 1967. Quantitative samples have been taken monthly with a modified marsh net (fig. 8) at 22 widely distributed shallow-water sites. Earlier samples were taken with the unit-area suction sampler designed by personnel at this station. Examination of samples from Florida Bay revealed that early juveniles increase in abundance during the summer and become most numerous during the fall. This concurs with the observation that postlarvae enter Florida Bay before and during these seasons.

The data we have collected on incoming postlarvae and early juveniles indicate that the distribution of early juvenile pink shrimp in Florida Bay depends primarily on the degree of postlarval penetration. Maximum concentrations of early juveniles occur in the western

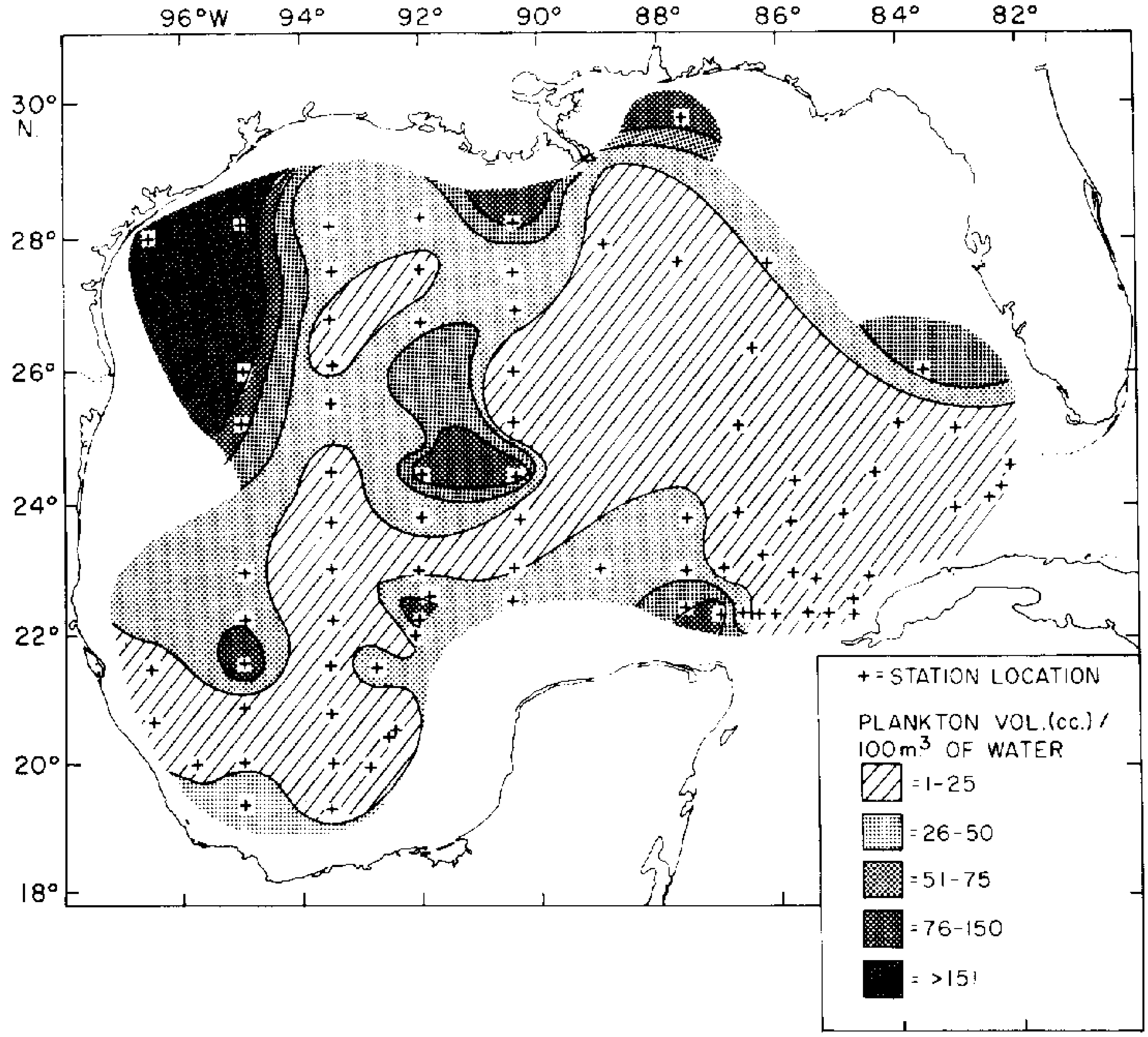


Figure 6.--Plankton volumes collected from the upper 100 meters (55 fathoms) of water during February and March 1967.

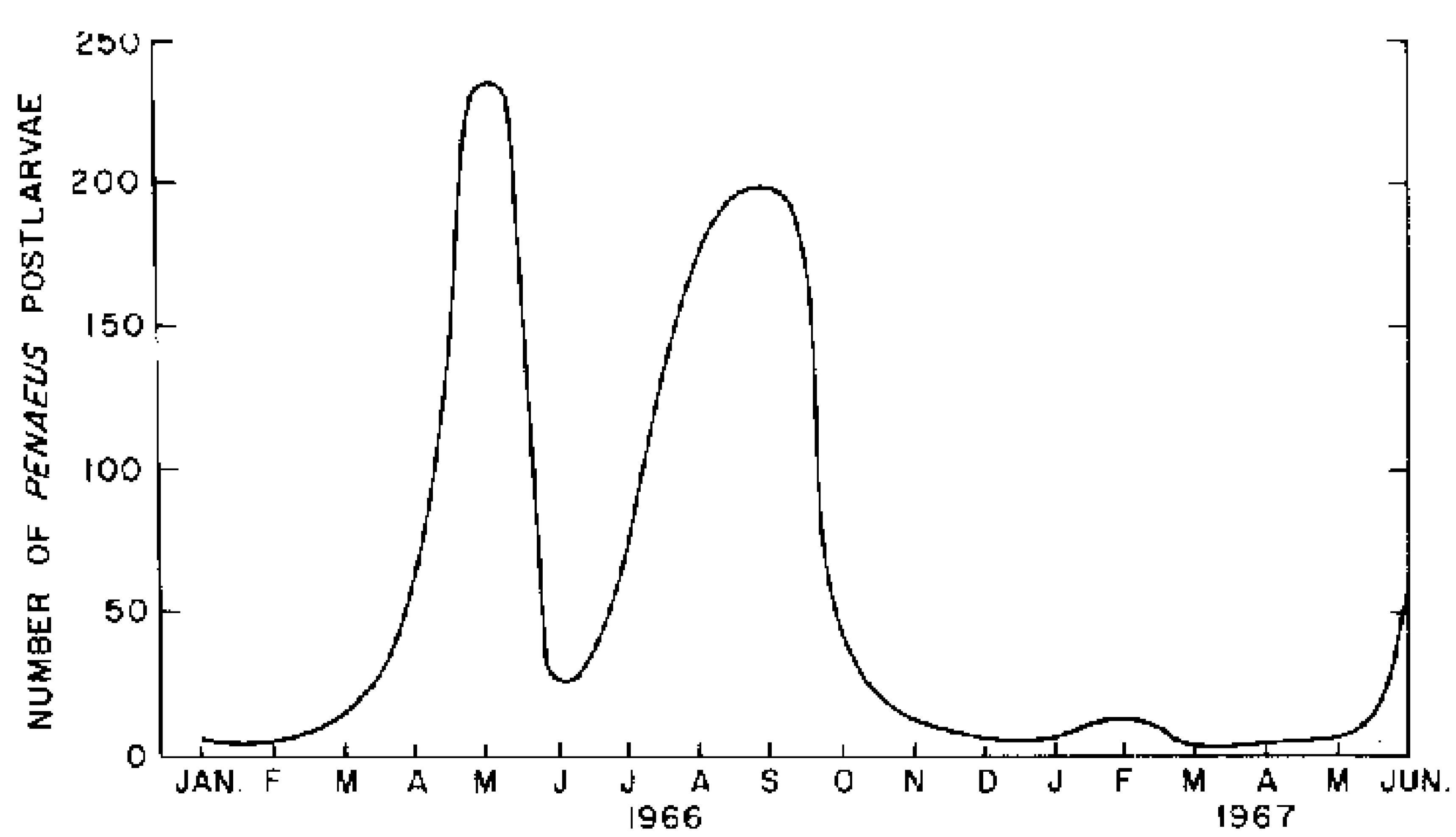


Figure 7.--Seasonal abundance of Penaeus postlarvae at Whale Harbor Bridge in upper Florida Keys, 1966-67. (Average monthly catch per standard unit of effort.)

and southern portions of the Bay, generally in areas that receive large volumes of waterflow from the Gulf of Mexico and the Atlantic Ocean--a demonstrated source of postlarvae. Conversely, northeastern Florida Bay, which receives little waterflow from these sources, contains few early juveniles. At three stations in the northeastern Bay, we collected no pink shrimp during the first 6 months of sampling.

The western and southern portions of the Bay are characterized by more stable salinities and temperatures, lower turbidities, and more extensive seagrass beds than generally occur in northeastern Florida Bay. In certain parts of northeastern Florida Bay, however, environmental conditions suitable for young pink shrimp apparently do exist for extended periods of time. Even at these times, however, few juveniles occur in northeastern Florida Bay.

Another important aim of the field work is to accumulate information needed as background for "estuary-seeding" experiments. If production of juvenile shrimp in Florida Bay depends on the availability of postlarvae, it may be feasible to introduce large numbers of young shrimp reared artificially to certain shrimp-deficient areas of the bay and thereby increase production. Sampling has established the usual abundance of pink shrimp and associated organisms at each station. With these background data, we may be able to determine the effect of introducing large numbers of young shrimp at a chosen location.

Thomas J. Costello, Project Leader
Donald M. Allen

Figure 8.--Modified marsh net with retrieving line and bridle, for sampling juvenile shrimp.

SEASONAL CHANGES IN RELATIVE ABUNDANCE OF POSTLARVAE OF PINK SHRIMP ENTERING THE EVERGLADES ESTUARY

During the fiscal year, sampling for postlarval pink shrimp, Penaeus duorarum, continued in Little Shark River and Buttonwood Canal, Everglades National Park, Fla. Paired surface and bottom hauls, each of 10-minute duration, were made at about 45- to 60-minute intervals during night flood tides. When shrimp were abundant, samples were taken on each of the four major moon phases. During the winter, when abundance was lower, samples were taken only in new- and full-moon periods. A total of 35 trips to each collecting site produced 105 paired bottom and surface samples at Buttonwood Canal and 117 at Little Shark River.

Abundance of postlarvae was highest in July when the production of shrimp per 1 $m.^3$ of water strained was 28.9 in Buttonwood Canal and 7.7 in Little Shark River. Catches were highest during new- and first-quarter-moon phases, and the bottom net consistently produced higher catches than the surface net. Maximum catch per 1 $m.^3$ for each sampling trip to Buttonwood Canal and Little Shark River is shown in figure 9. Experiments are being made to determine if the apparent concentration of postlarvae near the bottom is real or is caused by the movement of the vessel (which may cause the postlarvae to sound).

After we discovered that shrimp reacted to salinity gradients in aquaria, sampling procedures were modified slightly to include collection of salinity samples before the start of the night's fishing and at the midtime of each tow. These samples permit the measurement of salinity change in the time period represented by each tow.

The relation between carapace length and total length of shrimp less than 4mm. (0.2 inch) carapace length is being examined as well as

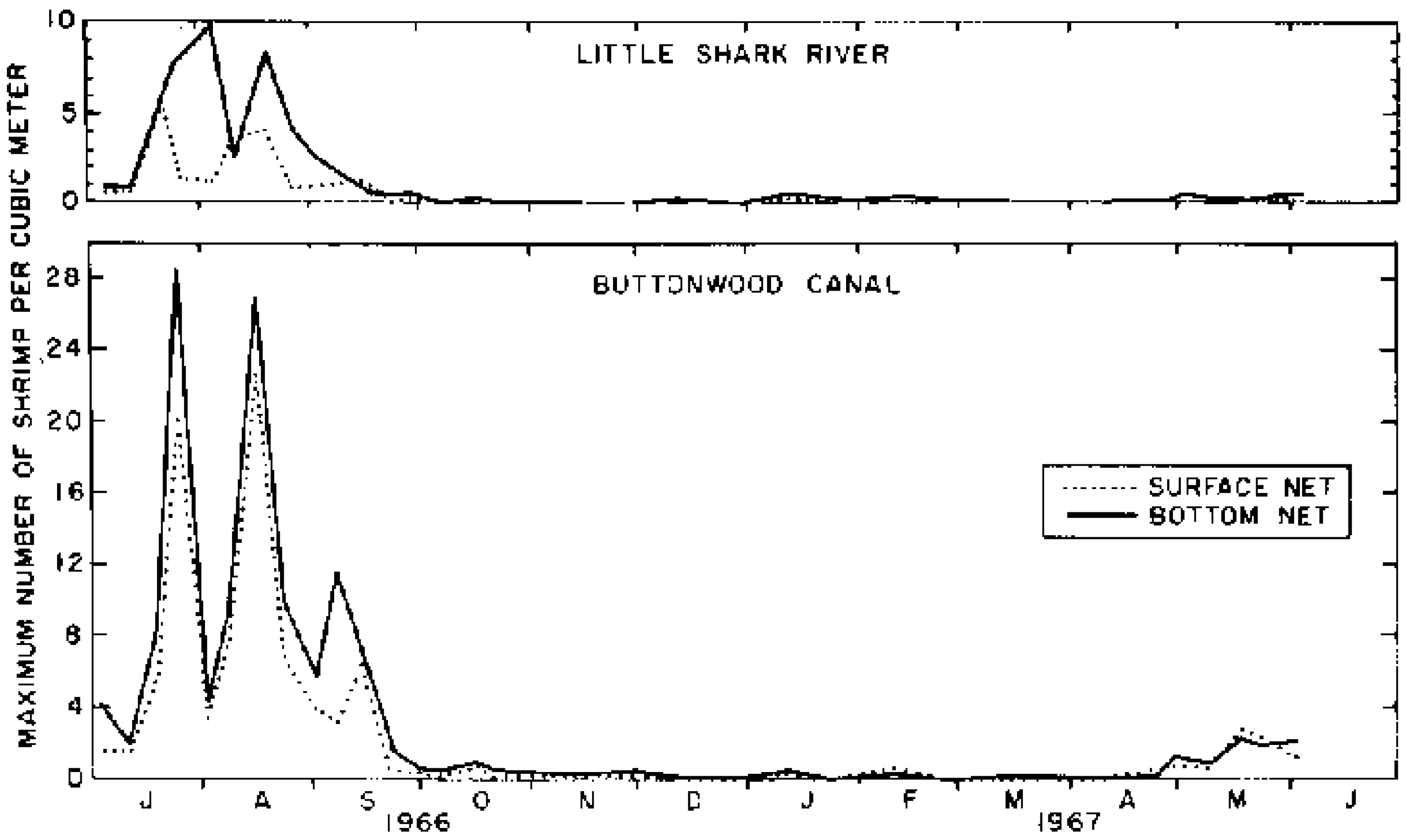


Figure 9.--Catches of postlarval pink shrimp entering Little Shark River and Buttonwood Cannal, July 1966 to June 1967.

the relations among spine count, season, moon phase, and area. It appears that older shrimp (i.e., those with more spines) occur in winter and that there is a lunar cycle in their occurrence which may be related to the number of hours of night flood tides in excess of night ebb tides.

Programs have been written for recording catch and environmental data on tapes and for summarizing the physical and biological measurements. Analysis of the data by using multivariate statistics after appropriate transformations will begin after the completion of field and sorting work. These programs were developed for work on juvenile shrimp data, and should require little modification for use with postlarval catch data.

C. P. Idyll and M. A. Roessler
Project Leaders

Institute of Marine Sciences,
University of Miami
(Contract No. 14-17-0002-187)

VARIATIONS IN ABUNDANCE OF JUVENILE PINK SHRIMP EMIGRATING FROM THE EVERGLADES NATIONAL PARK ESTUARY TO THE COMMERCIAL CATCH

The relative abundance of emigrating juvenile pink shrimp was determined in the past by sampling at a single station in Buttonwood Canal with a channel net. After extensive tests with several types of gear, we learned that reliable subsamples of the migrants could be taken with light, mobile "wing nets." The development of this gear made it possible to establish a second sampling station in upper Joe River (the major outlet in the estuary) in the western outlet of Whitewater Bay, and thereby improve the accuracy of the abundance estimates.

The relative abundance of juvenile shrimp in Buttonwood Canal varied during 1966. The highest peak of abundance in July was followed by an abrupt drop to a low level in August. A minor peak appeared in September, and thereafter abundance remained low. In the first half of 1967 a minor peak occurred in February and abundance was increasing in June (fig. 10).

At Joe River station, there were three periods of high relative abundance during 1966. The first and smallest was in January, the second was in June, and the third and largest was in September. In the first half of 1967, the pattern was similar to that in 1966; a peak occurred in January and a period of high abundance was developing in June (fig. 10).

A comparison of the abundance at the two stations shows that periods of abundance in Buttonwood Canal correspond reasonably well with those in Joe River, except that peaks may occur at the latter station 1 month before they do in Buttonwood Canal.

A comparison of the mean monthly sizes of shrimp at the two stations shows that shrimp were consistently larger in Joe River than in Buttonwood Canal. On an annual basis (July 1966 to June 1967), shrimp from Joe River averaged 2.5 mm. (0.1 inch) carapace length larger than shrimp from Buttonwood Canal. Mean sizes differed by as much as 4.8 mm. (0.2 inch) carapace length in some months.

Analysis of the data for 1966 provides the first opportunity to compare the abundance of shrimp at the two stations with the commercial catch of small shrimp on an annual basis. Periods of abundance in Buttonwood Canal corresponded, in general, to subsequent peaks of abundance in the commercial catch, but this relation was not as apparent as in earlier years. The data from Joe River, however, showed a good relation to the commercial catch. Three periods of high abundance were observed which corresponded well with three subsequent periods of increased abundance of small shrimp on the grounds. Lag periods for the Joe River

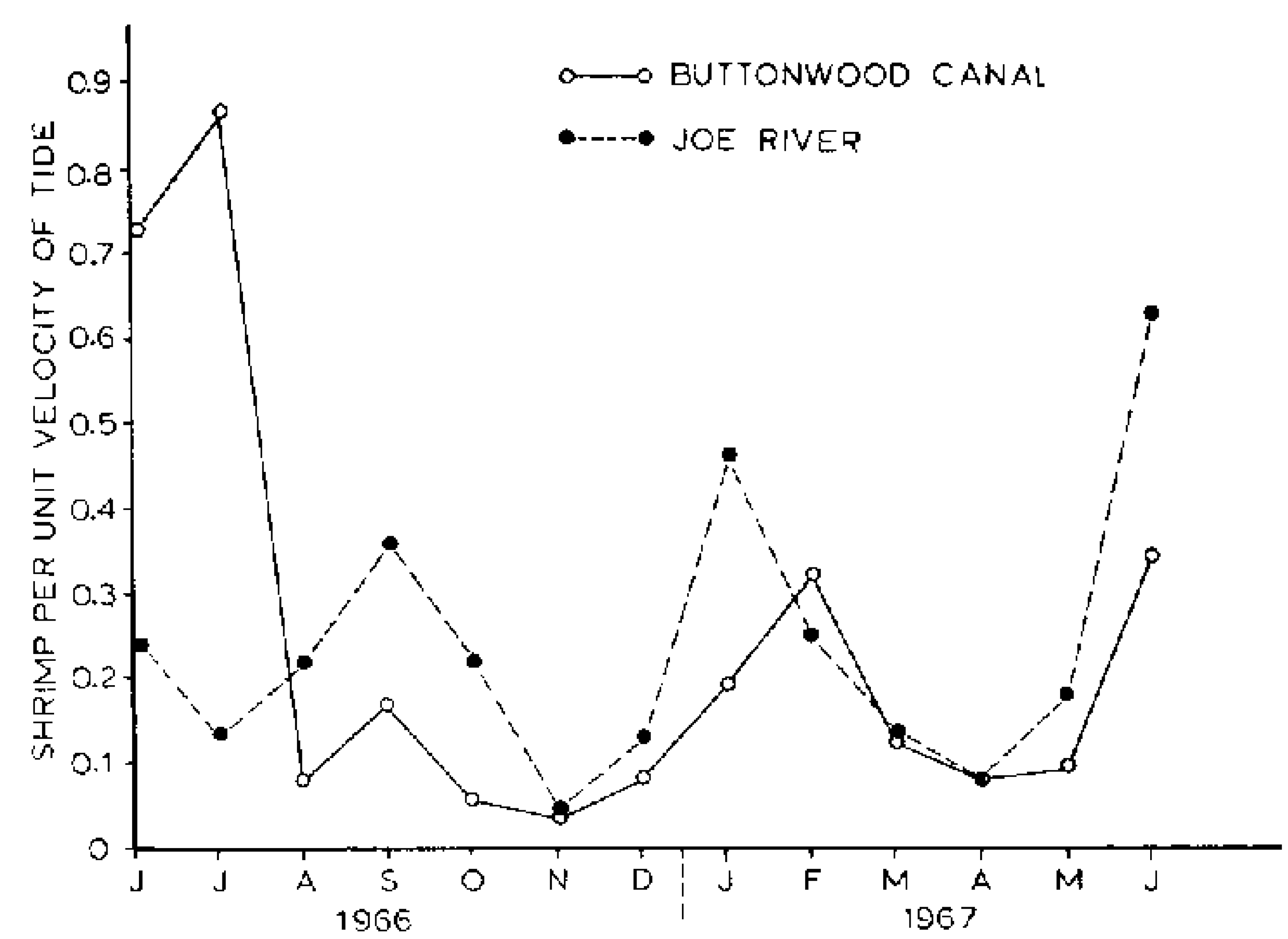


Figure 10.--Relative abundance of juvenile pink shrimp emigrating from two stations in the Everglades National Park estuary.

fishery harvest from U.S coastal waters, and most species contributing to this harvest are dependent on estuaries during either some stage of their development or their entire life.

The major purpose of our Estuarine Program is to document the dependency of fishery resources on estuaries, to determine the types of estuarine habitat that are most important, and to assess the value of these habitats in terms of production of renewable fishery resources. We are making additional efforts to determine how fishery resources are affected by modifications of the estuarine environment, how to prevent excessive damage, how to restore altered areas, and how to improve low-value habitats.

During the year, we developed new sampling techniques and gear for studying the behavior of brown and white shrimp emigrating in the Galveston Entrance. Resulting data on size and time of emigration were provided to State personnel and were used by them to manage their shrimp fishery. Ultimately, after refinement of the sampling techniques and their application, it should be possible to assess the contributions of a specific estuary to the population of harvestable species in the Gulf of Mexico. Such information is essential for establishing fishery values of estuaries.

We also have learned that vegetation along shorelines and beds of submerged plants in shallow water are major nursery habitats for young shrimp and many species of fish. Destruction of the vegetation by bulkheading, channel dredging, or spoil (from hydraulic dredges) eliminates these zones as nurseries. This knowledge has proven valuable in our assessment of probable effects of private construction projects and has been responsible for conserving vital habitats in Texas estuaries.

Our first efforts to transplant and establish emergent vegetation on hydraulically deposited spoil in a shallow bay were partially successful. We learned how to stabilize the clumps and determined the most suitable water depth for vigorous growth. We still do not know, however, how to accomplish these transplantings economically over large areas.

We have negotiated successfully with the Corps of Engineers for a hydraulic model testing program that will provide the information we need to evaluate how their hurricane protection plans will affect the hydrology of Galveston Bay. Through this cooperative effort, we may develop a proposal that will provide hurricane protection without impairing the value of the estuary for fishery resources.

Charles R. Chapman, Program Leader

EFFECTS OF ENGINEERING PROJECTS

Development of coastal areas to meet human demands usually requires a considerable amount of land and water alteration and rearrangement. Consequently, deterioration or destruction, or both, of estuarine habitat results from construction projects involving tributary control of fresh water, channel dredging, filling, bulkheading, marsh drainage, diking, levees, and salt-water barriers.

Work by private interests in navigable waters requires a permit from the U.S. Army Corps of Engineers. Pursuant to the Fish and Wildlife Coordination Act, the Bureau of Sport Fisheries and Wildlife's Division of River Basin Studies is responsible for advising the Corps of possible adverse effects that the proposed work might have on fish and wildlife resources. Frequently, construction plans must be modified to reduce or eliminate damage to natural resources. We assist personnel of the Division of River Basin Studies in evaluating all private construction projects in the coastal areas of the western Gulf of Mexico. The number, type, and general location of applications for private construction reviewed during the fiscal year are listed in table 7.

In addition to private construction projects, we also review and evaluate Federal water-use projects and occasionally ones proposed by the Soil Conservation Service and Bureau of Reclamation. Additionally, during fiscal year 1967, project personnel contributed to and reviewed drafts of 42 Bureau of Sport Fisheries and Wildlife Reports on private and Federal construction projects.

It is important that we be capable of determining specific effects of water-development projects on fishery resources so that we can recommend feasible measures for lessening the severity of damage or for increasing habitat quality of previously damaged areas. Methods must be developed for accurately predicting long-range and immediate ecological changes resulting from different types of construction. We also must develop measures for preventing damage to the estuaries as well as for rehabilitating or improving them.

Effects of Habitat Modification

Studies have been started to determine how the estuarine biota is affected by environment modifications resulting from channelization, hydraulic spoiling, bulkheading, and filling (fig. 15). The study area includes a location that is being developed for housing sites and a nearby unaltered area that is being studied as a control. Both areas are typical small bays with about 80 hectares (200 acres) of open water, beds of submerged aquatic vegetation, and extensive peripheral tidal marshes.

Biological, hydrological, and physical features of both areas were assessed before construction to provide a basis for comparing effects during and after development. These

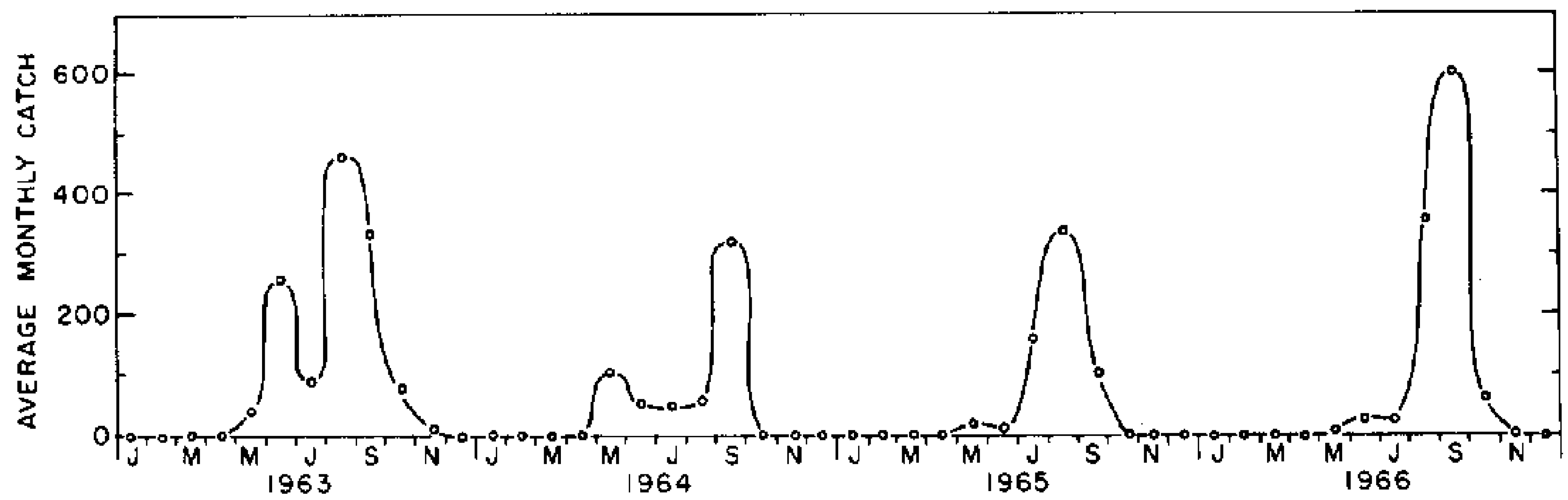


Figure 14.--Abundance of postlarval white shrimp, Sabine Pass, Tex., 1963-66. Open circles represent averages of four tows per month.

to a depth of 14.5 m. (8 fathoms) off Galveston was completed in March. This investigation was undertaken to determine the role of currents in transporting postlarval shrimp. The data are now being analyzed.

A cooperative inshore current study between our Laboratory and the Institute of Marine Science at Port Aransas, Tex., began in October. Institute personnel are releasing drift bottles monthly at depths of 0.9, 12, and 14.5 m. (3, 6, and 8 fathoms) at 18 stations between Port Aransas and Port Isabel, Tex.

Kenneth N. Baxter, Project Leader

STUDIES OF POSTLARVAL SHRIMP IN VERMILION BAY

Prediction of Commercial Harvest

Systematic sampling for immigrating postlarval shrimp continued in Vermilion and Cote Blanche Bays, La. These studies are designed to investigate seasonal fluctuations in abundance and to determine indices for predicting the abundance of juvenile and subadult shrimp in the bays.

The abundance of postlarval brown shrimp in 1966 indicated that the commercial bay harvest of juvenile and subadult brown shrimp would equal or exceed those of the previous 3 years. The 1966 harvest was 153,000 kg. (336,000 pounds), and the annual average catch per trip was 56 kg. (123 pounds); both greatly exceeded similar catches for 1963-65.

The abundance index for postlarval white shrimp in 1966 indicated that the white shrimp harvest would be relatively low. The harvest, 369,000 kg. (811,000 pounds), exceeded the 1965 catch but was lower than either the 1963 or 1964 production. The annual average catch of white shrimp per trip was 135 kg. (297 pounds), slightly more than half that of 1965.

Postlarval Shrimp Identification

Electrophoretic, serological, and immunoelectrophoretic techniques were investigated as possible methods of identifying postlarvae of brown and white shrimp. Proteins from postlarval and adult shrimp had similar electrophoretic patterns, but postlarval material yielded an additional protein band that may be characteristic of this stage. This method shows promise as a routine technique for identification of postlarval shrimp.

Charles W. Caillouet, Jr., Project Leader
University of Southwestern Louisiana
(Contract No. 14-17-0002-179)

ESTUARINE PROGRAM

The increasing national attention being focused on the estuaries emphasizes their importance and the need for strong research programs to develop the facts to preserve them and to manage their fishery resources. The increasing rate of physical destruction of estuarine areas by residential, commercial, industrial, and agricultural expansion is readily evident. During the fiscal year, more than 435 private projects were proposed for various types of construction in the coastal waters and marshes of Texas.

In recent years, about 16 percent of the 17,401 hectares (430,000 acres) of water and marsh in Galveston Bay has been destroyed, severely damaged, or isolated; another 6 percent soon will be converted to a fresh-water lake. If this destructive trend is to be halted, the public, construction planner, administrators, and legislators must be informed repeatedly of the value of estuaries as a natural resource which contributes significantly to our national economy and to the well-being of our people.

The role of estuaries in perpetuating renewable fishery resources is but one of its values, but this value is great. The Gulf of Mexico contributes one-third of the total commercial

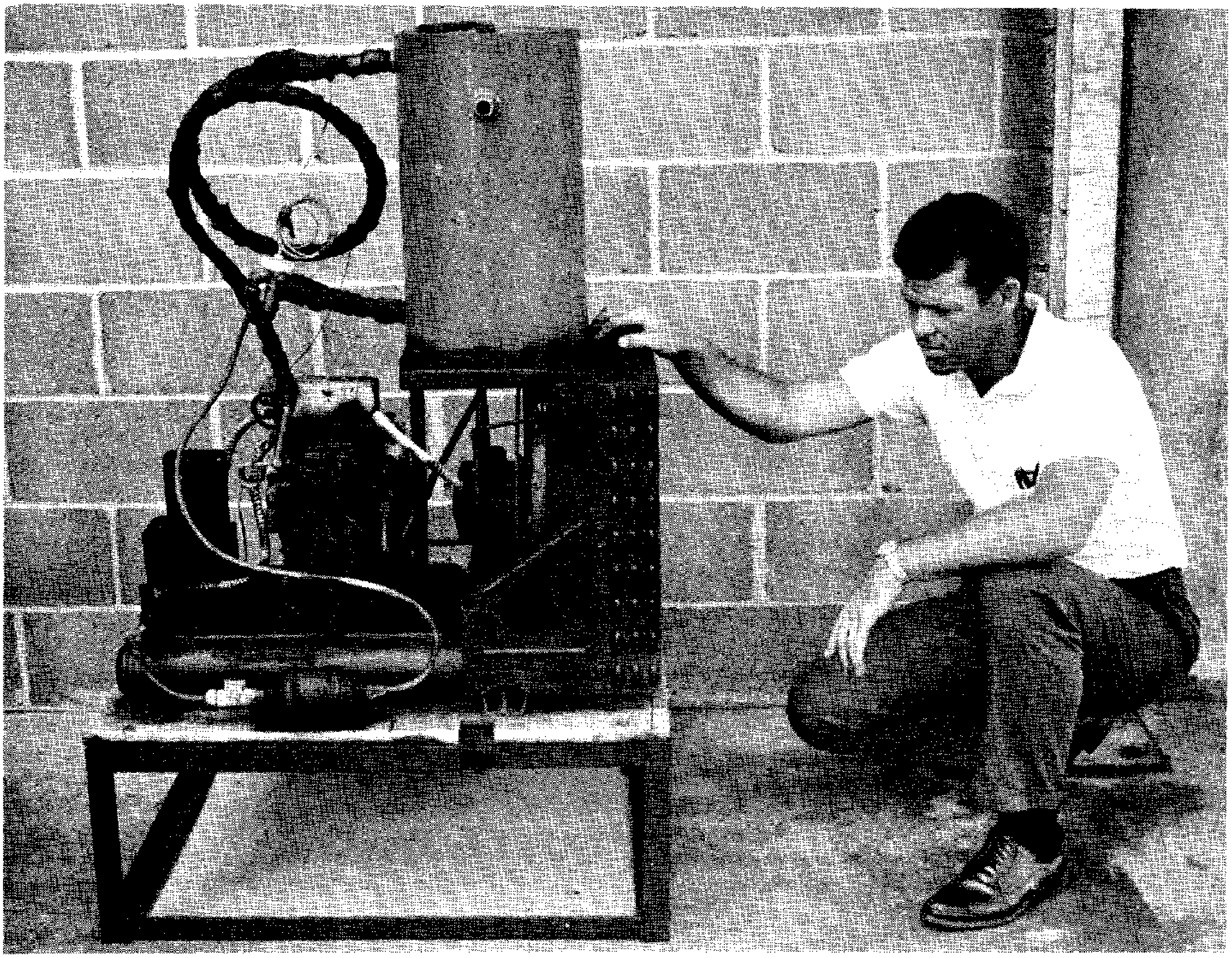


Figure 11.--Lightweight refrigeration unit for cooling water in holding tanks.

the acceptability of the polyvinyl chloride tag and that of the Vaseline-pigment secondary mark.

Richard A. Neal, Project Leader

POSTLARVAL AND JUVENILE SHRIMP

We have learned that abundance indices of the postlarval and juvenile life history stages of brown shrimp can be used to predict the subsequent abundance of adults. The juvenile index is more reliable, but predictions based on postlarval indices have a greater potential value because information is available about 2 months sooner. In 6 of the 7 years for which data are available, indices of abundance of juvenile brown shrimp, developed from Galveston Bay bait shrimp fishery statistics, have portrayed the general magnitude of the adult brown shrimp harvest along the entire Texas coast.

Table 6.--Comparison of the survival time of shrimp marked with biological stain and with biological stain plus fluorescent pigments

Mark	Shrimp	Mean survival time
	Number	Days
Control	60	17.97
Biological stain	60	17.05
Biological stain plus fluorescent pigment	240	14.70

Postlarvae

Systematic sampling for immigrating postlarval shrimp continued at Galveston and at

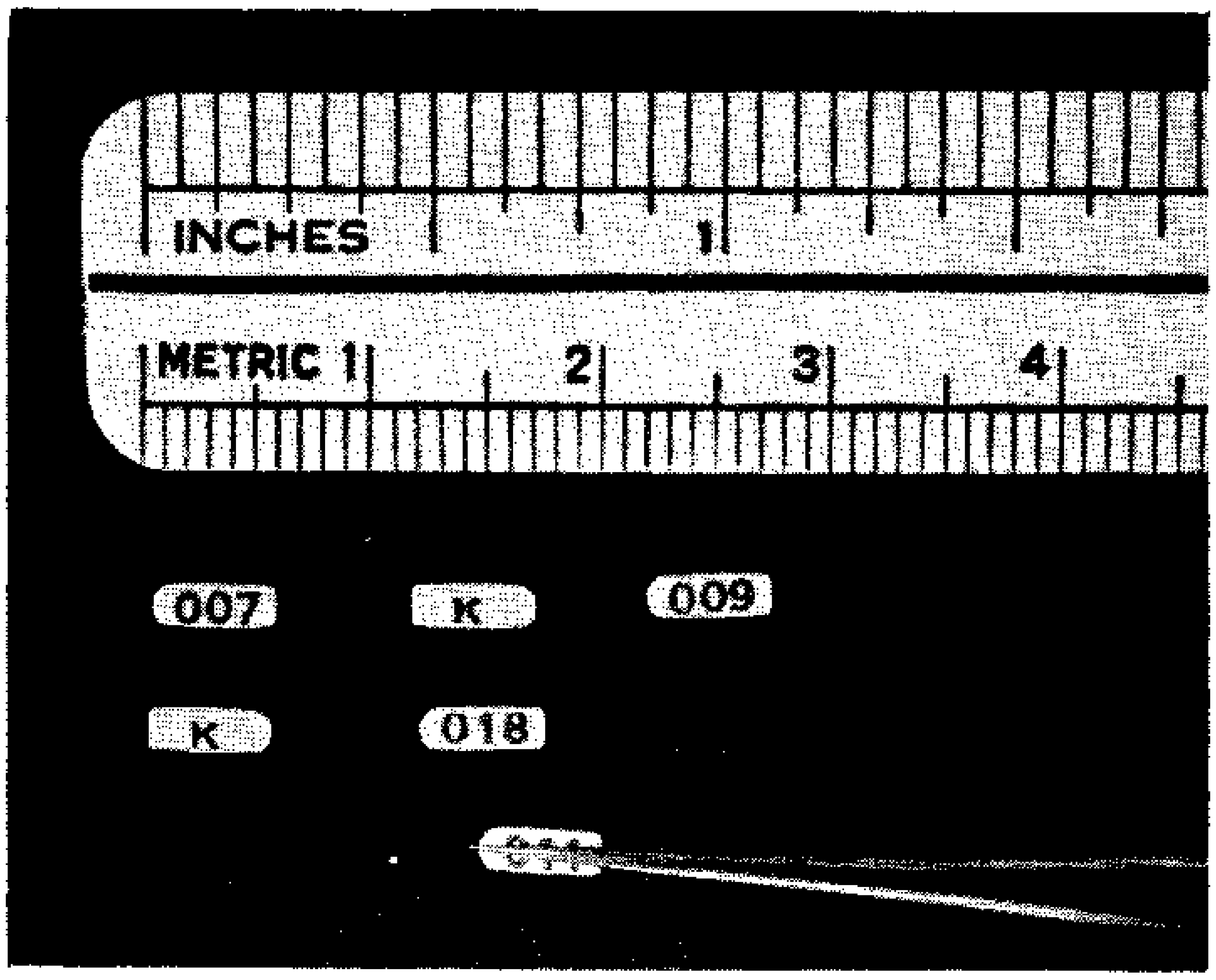


Figure 12.--Internal plastic shrimp tags.

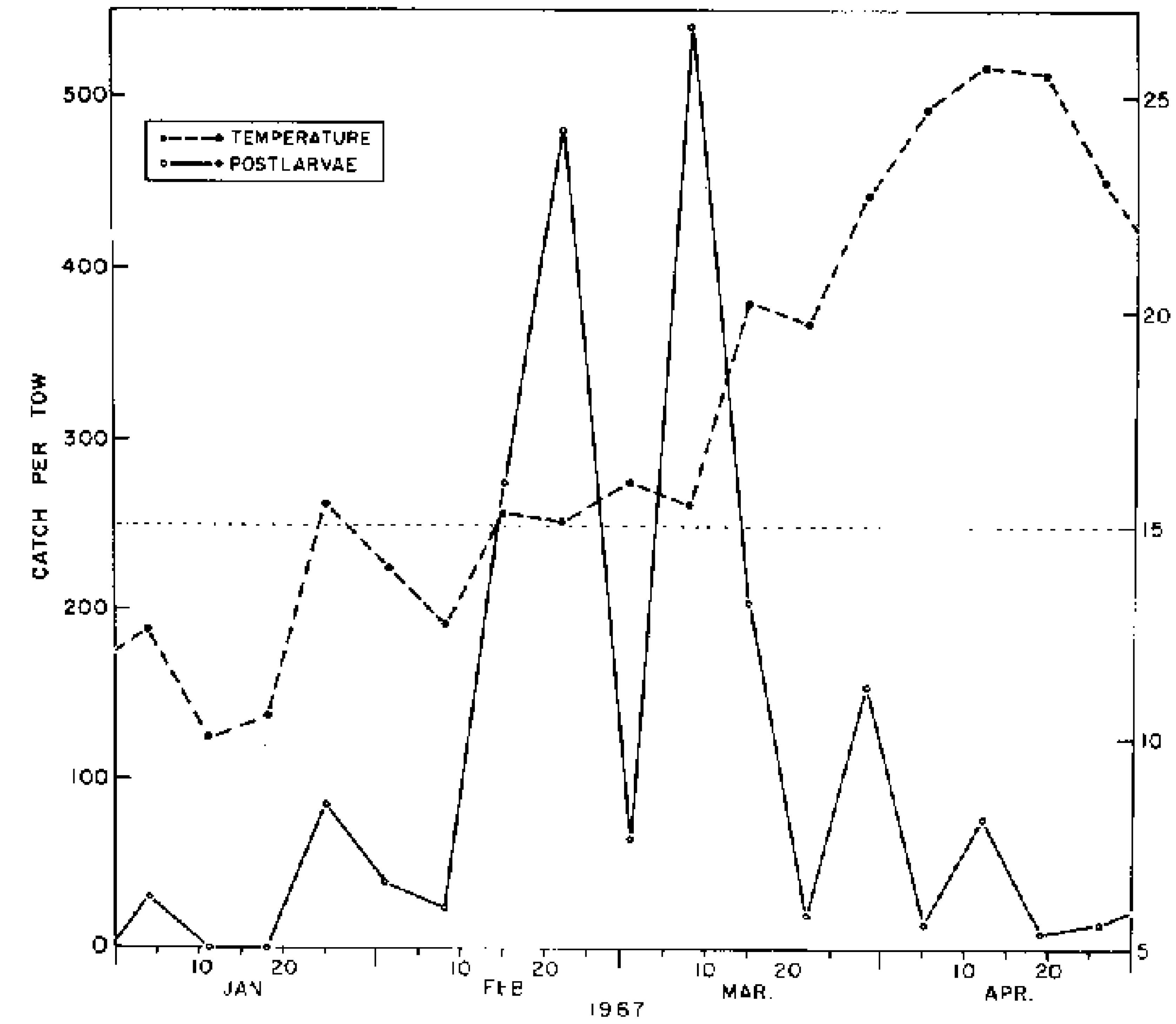


Figure 13.--Weekly water temperatures and indices of abundance of postlarval brown shrimp at Galveston Entrance in early 1967.

Sabine Pass, Tex. Between late February and mid-March 1967, postlarval brown shrimp entered Galveston Bay in two major groups 2 weeks apart (fig. 13). The large April influx of postlarvae, usually reflected by our sampling, did not appear in 1967. Average weekly water temperature remained above 15° C. (59.0° F.) after February 15.

Postlarval white shrimp were collected in sample catches in late April, but numbers did not increase significantly at either the Galveston or Sabine Pass sampling stations through mid-June. The early-summer bay crop of juvenile and subadult white shrimp will probably be small. In most years, catches of postlarval white shrimp increase at bay entrances during the spring and fall. The first group arrives at the tidal passes in May-June and the second in August-September. For the past 4 years, early fall collections have contained more postlarval white shrimp than spring collections, especially at Sabine Pass (fig. 14).

An apparent limitation of past postlarval shrimp data is the small number of samples taken during periods of greatest abundance. We are building a plankton pumping device that will sample incoming postlarvae at frequent intervals or continuously during periods of peak immigration. A working model has been used successfully at the East Lagoon laboratory in preliminary tests.

Juvenile Shrimp

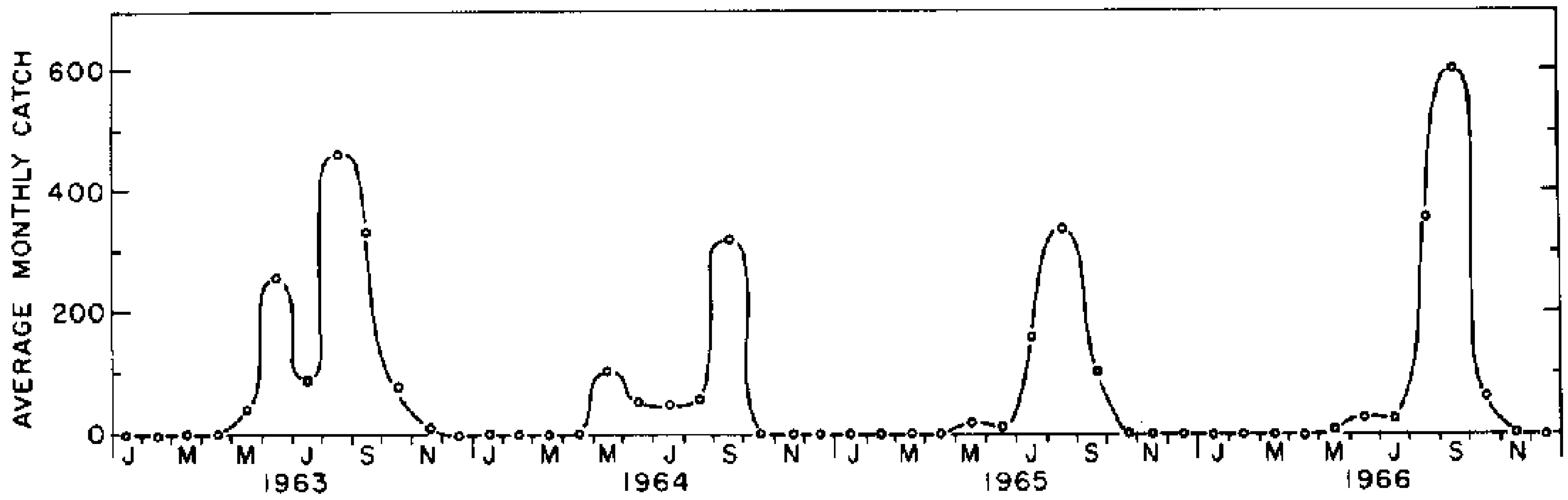
Young brown shrimp apparently encountered favorable conditions for survival and growth on the nursery grounds in 1967. By mid-April they were being taken by commercial bait-shrimp fishermen, and by early May their abundance in this fishery appeared to be reaching peak proportions. Indices of abundance for postlarval and juvenile brown shrimp indicate a large harvest of adult brown shrimp in the late summer and fall of 1967.

Result of our weekly survey of the bait-shrimp fishery of Galveston Bay indicate that this fishery in 1966 experienced its poorest harvest of young brown shrimp since detailed statistical coverage began in 1959. Juvenile brown shrimp abundance, as reflected by catch-effort statistics, decreased by 50 percent in 1966 as compared with 1965. This decline may have been caused by the unusually large inflow of fresh water into the Galveston Bay system from the Trinity River and its tributaries in May. The resultant lowered salinities for an extended period during the peak growing time for brown shrimp possibly caused most shrimp of the year class to move offshore prematurely, thus making them unavailable to the bay fishermen. Early departure of young brown shrimp coupled with a sparse crop of white shrimp in the bay evidently caused the poor catch by bay fishermen in 1966.

We continued to prepare monthly summaries of the bait-shrimp fishery of Galveston Bay, including catch, effort, and number of active dealers and fishermen. These summaries are distributed to State agencies, universities, and individuals upon request.

Inshore Current Patterns

A 1-year drift bottle and seabed drifter study of inshore current patterns from shore



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The abundance index for postlarval white shrimp in 1966 indicated that the white shrimp harvest would be relatively low. The harvest, 369,000 kg. (811,000 pounds), exceeded the 1965 catch but was lower than either the 1963 or 1964 production. The annual average catch of white shrimp per trip was 135 kg. (297 pounds), slightly more than half that of 1965.

Postlarval Shrimp Identification

Electrophoretic, serological, and immunoelectrophoretic techniques were investigated as possible methods of identifying postlarvae of brown and white shrimp. Proteins from postlarval and adult shrimp had similar electrophoretic patterns, but postlarval material yielded an additional protein band that may be characteristic of this stage. This method shows promise as a routine technique for identification of postlarval shrimp.

Charles W. Caillouet, Jr., Project Leader
University of Southwestern Louisiana
(Contract No. 14-17-0002-179)

ESTUARINE PROGRAM

The increasing national attention being focused on the estuaries emphasizes their importance and the need for strong research programs to develop the facts to preserve them and to manage their fishery resources. The increasing rate of physical destruction of estuarine areas by residential, commercial, industrial, and agricultural expansion is readily evident. During the fiscal year, more than 435 private projects were proposed for various types of construction in the coastal waters and marshes of Texas.

In recent years, about 16 percent of the 17,401 hectares (430,000 acres) of water and marsh in Galveston Bay has been destroyed, severely damaged, or isolated; another 6 percent soon will be converted to a fresh-water lake. If this destructive trend is to be halted, the public, construction planner, administrators, and legislators must be informed repeatedly of the value of estuaries as a natural resource which contributes significantly to our national economy and to the well-being of our people.

The role of estuaries in perpetuating renewable fishery resources is but one of its values, but this value is great. The Gulf of Mexico contributes one-third of the total commercial fishery harvest from U.S coastal waters, and most species contributing to this harvest are dependent on estuaries during either some stage of their development or their entire life.

The major purpose of our Estuarine Program is to document the dependency of fishery resources on estuaries, to determine the types of estuarine habitat that are most important, and to assess the value of these habitats in terms of production of renewable fishery resources. We are making additional efforts to determine how fishery resources are affected by modifications of the estuarine environment, how to prevent excessive damage, how to restore altered areas, and how to improve low-value habitats.

During the year, we developed new sampling techniques and gear for studying the behavior of brown and white shrimp emigrating in the Galveston Entrance. Resulting data on size and time of emigration were provided to State personnel and were used by them to manage their shrimp fishery. Ultimately, after refinement of the sampling techniques and their application, it should be possible to assess the contributions of a specific estuary to the population of harvestable species in the Gulf of Mexico. Such information is essential for establishing fishery values of estuaries.

We also have learned that vegetation along shorelines and beds of submerged plants in shallow water are major nursery habitats for young shrimp and many species of fish. Destruction of the vegetation by bulkheading, channel dredging, or spoil (from hydraulic dredges) eliminates these zones as nurseries. This knowledge has proven valuable in our assessment of probable effects of private construction projects and has been responsible for conserving vital habitats in Texas estuaries.

Our first efforts to transplant and establish emergent vegetation on hydraulically deposited spoil in a shallow bay were partially successful. We learned how to stabilize the clumps and determined the most suitable water depth for vigorous growth. We still do not know, however, how to accomplish these transplantings economically over large areas.

We have negotiated successfully with the Corps of Engineers for a hydraulic model testing program that will provide the information we need to evaluate how their hurricane protection plans will affect the hydrology of Galveston Bay. Through this cooperative effort, we may develop a proposal that will provide hurricane protection without impairing the value of the estuary for fishery resources.

Charles R. Chapman, Program Leader

EFFECTS OF ENGINEERING PROJECTS

Development of coastal areas to meet human demands usually requires a considerable amount of land and water alteration and rearrangement. Consequently, deterioration or destruction, or both, of estuarine habitat results from construction projects involving tributary control of fresh water, channel dredging, filling, bulkheading, marsh drainage, diking, levees, and salt-water barriers.

Work by private interests in navigable waters requires a permit from the U.S. Army Corps of Engineers. Pursuant to the Fish and Wildlife Coordination Act, the Bureau of Sport Fisheries and Wildlife's Division of River Basin Studies is responsible for advising the Corps of possible adverse effects that the proposed work might have on fish and wildlife resources. Frequently, construction plans must be modified to reduce or eliminate damage to natural resources. We assist personnel of the Division of River Basin Studies in evaluating all private construction projects in the coastal areas of the western Gulf of Mexico. The number, type, and general location of applications for private construction reviewed during the fiscal year are listed in table 7.

In addition to private construction projects, we also review and evaluate Federal water-use projects and occasionally ones proposed by the Soil Conservation Service and Bureau of Reclamation. Additionally, during fiscal year 1967, project personnel contributed to and reviewed drafts of 42 Bureau of Sport Fisheries and Wildlife Reports on private and Federal construction projects.

It is important that we be capable of determining specific effects of water-development projects on fishery resources so that we can recommend feasible measures for lessening the severity of damage or for increasing habitat quality of previously damaged areas. Methods must be developed for accurately predicting long-range and immediate ecological changes resulting from different types of construction. We also must develop measures for preventing damage to the estuaries as well as for rehabilitating or improving them.

Effects of Habitat Modification

Studies have been started to determine how the estuarine biota is affected by environment modifications resulting from channelization, hydraulic spoiling, bulkheading, and filling (fig. 15). The study area includes a location that is being developed for housing sites and a nearby unaltered area that is being studied as a control. Both areas are typical small bays with about 80 hectares (200 acres) of open water, beds of submerged aquatic vegetation, and extensive peripheral tidal marshes.

Biological, hydrological, and physical features of both areas were assessed before construction to provide a basis for comparing effects during and after development. These

Table 7.--Number, type, and location of proposed private construction projects in western Gulf of Mexico coastal areas reviewed during fiscal year 1967

Location	Mineral development		Navigation channels	Bulkheading and fill	Other[1]	Total
	With channel dredging	Without channel dredging				
	Number	Number	Number	Number	Number	Number
Sabine Lake	1	1	0	2	2	6
Galveston Bay	12	20	5	5	20	62
Matagorda Bay	8	7	5	1	14	35
San Antonio Bay	4	6	0	0	5	15
Aransas-Copano Bay	2	16	1	0	14	33
Corpus Christi Bay	11	26	5	5	27	74
Laguna Madre	7	12	6	0	5	30
Gulf of Mexico	0	59	0	0	8	67
Rivers and streams	0	0	9	12	87	108
Louisiana bays	2	0	0	0	3	5
Total	47	147	31	25	185	435

[1] Includes pipelines, wharves, piers, bridges, and jetties.

studies revealed that penaeid shrimp and many important species of finfish used the intertidal marsh zones and the beds of submerged aquatic vegetation extensively as nursery habitat. Bottom sediments were relatively stable and similar in the two areas, and the water was clear for extended periods.

In the area being developed, the shoreline has been bulkheaded and marsh elevations are being raised by pumping mud and sand from nearby shallow-water areas (fig. 16). A channel has been dredged between the construction site and the deeper waters of the outer bay. Spoil has been dumped in large piles beside the channel, producing a widespread unstable layer of fine sand and silty clay which has made the water highly turbid for long periods. The occurrence, abundance, and distribution of marine fauna, particularly young penaeid shrimp, has decreased markedly. Also, the quantity and quality of submerged aquatic vegetation have been reduced significantly.

Habitat Rehabilitation

Because hydraulic spoil dumped on a vegetated shoreline or on beds of submerged aquatic vegetation completely rearranges and destroys productive estuarine habitat, we have begun a study to develop methods for establishing aquatic and marsh vegetation on barren spoil areas. This vegetation will reduce the area's vulnerability to erosion from wave action and will re-create a natural "edge" effect. Our first efforts were to transplant smooth cord grass, Spartina alterniflora, in the intertidal zone of a recent spoil deposit (fig. 17). To date, our first transplantings appear to be growing and spreading beyond the original planting site.

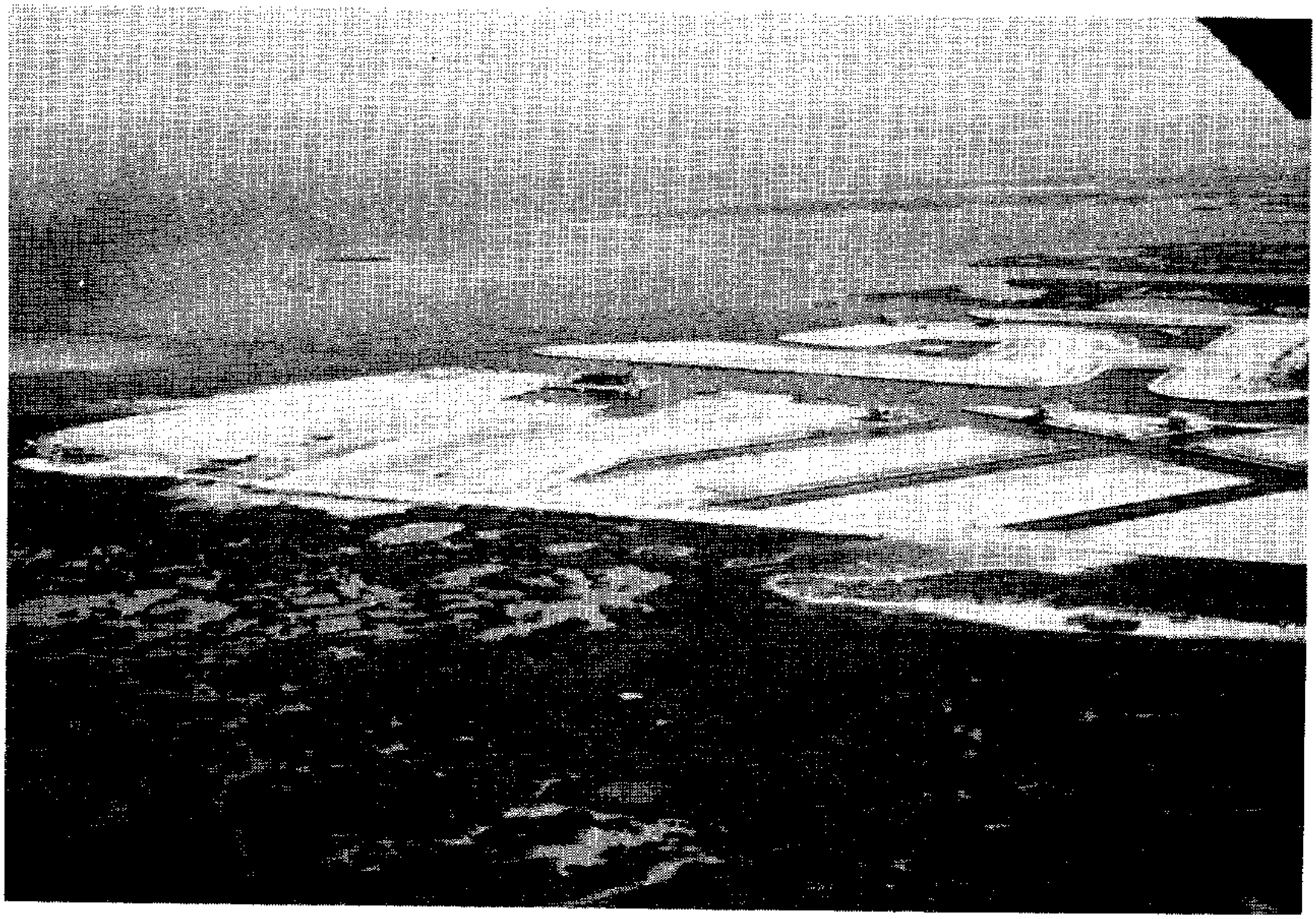

Figure 15.--Valuable estuarine nursery area being converted to housing development on west Galveston Island.

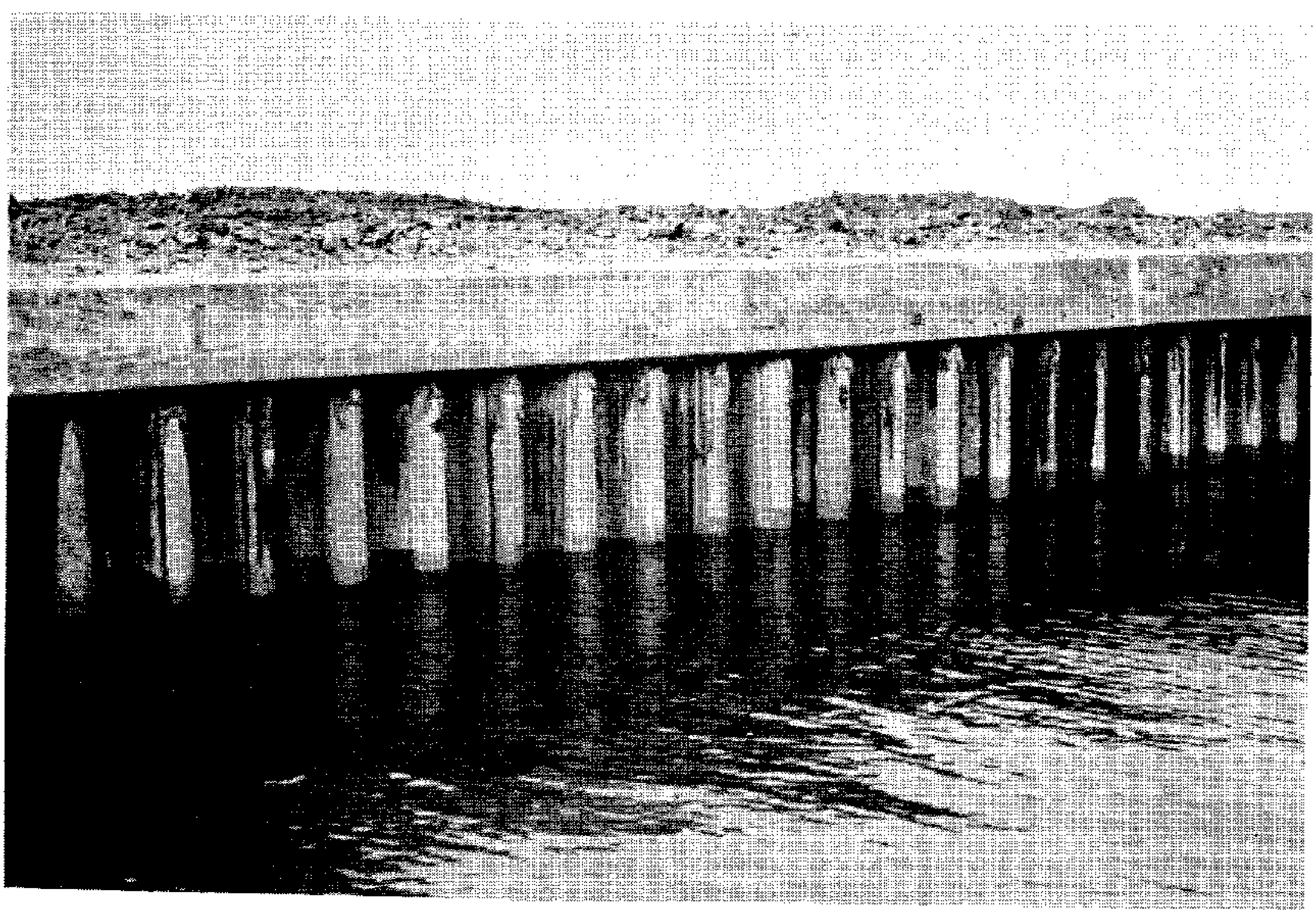

Figure 16.--A former nursery area on west Galveston Island has been developed for housing by bulkheading the natural shoreline and raising marsh elevation with fill from hydraulic dredging.

Figure 17.--Spartina alterniflora transplantings on recent hydraulically deposited spoil bank.

We are also experimenting with a synthetic fibrous material (fig. 18) to determine if it can, under certain circumstances, be substituted for natural vegetation. This material was attached to piers, bulkheads, and along barren shorelines to determine whether it would attract microfauna, penaeid shrimp, and other important estuarine species. Samples of the biota taken under and in the material were consistently more productive than samples from nonvegetated areas. The artificial habitat appears to be more attractive to some forms of marine life (including penaeid shrimp) than the natural habitat devoid of vegetation.

Texas Coast Hurricane Study Project

Considerable effort was devoted to planning and negotiating with the Corps of Engineers for appropriate hydraulic model tests that will assess the practicability of hurricane protection plans for the Galveston Bay area. The Corps of Engineers has constructed two hydraulic models to test inland penetration of hurricane surges and to determine how the proposed hurricane protection structures will affect the hydrology of Galveston Bay.

The small-scale model (scale: 1:3,000 horizontal; 1:100 vertical) will be used to study the penetration of storm surges. It will also be used to assess, by measuring water elevation, structural requirements in San Luis Tidal Pass to provide for the existing tidal range.

The larger scale Houston Ship Channel model (scale: 1:600 horizontal; 1:60 vertical) will be used to test and develop structures for hurricane protection that will not alter significantly the existing hydrology in the bay system (fig. 19). Fish and wildlife interests have selected the water year 1965 (October 1, 1964, to September 30, 1965) to represent base conditions for model testing. After verification of base conditions in the model, the hurricane protection plan will be introduced and the base period test repeated. Comparison of water elevation and salinity with and without the hurricane protection plan will provide a measure of change to be expected in the bay system. Through this cooperative effort, a proposal may be developed that will not only provide hurricane protection, but also will not significantly alter existing conditions.

A series of tests will be run in the large model to reflect partial diversion of the Trinity River waters to the Houston Ship Channel where they would enter the bay. The base-year period will be tested with and without the hurricane protection plan in place. If major hydrological changes occur with the protection plan in place, additional tests will be made with the necessary adjustments to maintain desired conditions.

Dye studies in which industrial and domestic pollution are simulated will be included in all

Figure 18.--Simulating a natural environment with an artificial synthetic fibrous material.

model testing to obtain information on the rate and pattern of pollution dispersion.

Updating and analysis of historical fishery harvest data of the Galveston estuary are continuing. These data will be used for projecting influences on fishery resources caused by the proposed plan for hurricane protection.

Richard J. Hoogland, Project Leader

ECOLOGY OF WESTERN GULF ESTUARIES

During the year we studied the hydrography of Galveston Bay, emigration of brown and white shrimp, and methods for identifying postlarval penaeid shrimp.

Hydrology

During 1966, temperature and salinity measurements were made monthly, or sometimes more frequently, at selected locations (fig. 20) in Galveston Bay. Although temperature and salinity values varied between areas within the bay during any one cruise, all data were combined and averaged by cruise to depict generally seasonal trends for the entire bay (fig. 21). Also included are river discharge data from the Trinity and San Jacinto Rivers, the two largest sources of fresh water flowing into Galveston Bay.

Average bottom water temperatures in the bay varied from 11.0° C. (51.8° F.) in December to 30.5° C. (86.9° F.) in July. The highest temperature, 36° C. (96.8° F.) was recorded in June, and the lowest, 5.0° C. (41.0° F.), in February and December. Usually, fluctuation in temperature throughout the bay on a particular date (indicated by the range in figure 21) was greatest from November to March.

Stream-flow records for the Trinity and San Jacinto Rivers indicate a large volume of stream discharge in May. It is apparent that this flow of fresh water affected bottom salinities throughout the bay. Average bottom salinities were reduced to 1 p.p.t. (part per thousand) in Trinity Bay and below 10 p.p.t. in lower Galveston and East Bays. Recovery of salinities to levels that existed before the high discharge required about 4 months in Trinity Bay.

The importance of water temperature in controlling the growth of brown shrimp and causing juvenile white shrimp to start emigrating from bays has been clearly demonstrated. Therefore, we are analyzing our data on temperature and shrimp catch per unit of effort in Galveston Bay to determine if water temperature can be used to predict the time that (1) brown shrimp first become available to the bait fishery and (2) white shrimp emigrate from the bay.

Figure 19.--The Galveston Bay model constructed by Corps of Engineers at Vicksburg, Miss., that will be used to test proposed plans for hurricane protection. (Galveston, Tex., is located at bottom of picture. Note the Houston Ship Channel extending the entire length of the dewatered model and the Texas City Channel extending from the center to the left, upper-central margin.)

Studies on the Emigration of Brown and White Shrimp

The use of closed seasons or minimum size limits to protect juvenile stages of commercially important species from commercial harvest is a common practice in the United States. Shrimping regulations for Texas coastal waters, for example, dictate a 45-day closed season during late spring and early summer to protect juvenile brown shrimp as they emigrate from the bays to offshore Gulf waters. This closure usually begins June 1 but can be adjusted to 15 days before or after June 1. The date of closure depends on the abundance and size of juvenile brown shrimp in the bays within a particular year.

To select the closure date, Texas Parks and Wildlife Department personnel depend on trawl samples of shrimp (catch per-unit-of-effort data) from the bays to estimate the time at which most of the shrimp are emigrating to the Gulf. Samples are taken from a broad area within each bay and are costly and time-consuming to obtain. Also, there is a lag (the duration of which is unknown) from the time that shrimp are abundant in the bays until they become abundant in near-shore Gulf waters.

More accurate and less costly information probably can be obtained on the size of shrimp and time of emigration by sampling in tidal passes if adequate sampling techniques are developed. Also, such techniques, when improved, will provide methods for estimating the relative (or absolute) contribution by each bay of selected species to the offshore fisheries.

We began sampling for shrimp at station 1 (see fig. 20) in the Galveston tidal pass in May 1966 and continued through January 1967. A 0.6- by 3.0-m. (2- by 10-foot) net was used during the brown shrimp study. For each series of samples, the trawl was towed for 8 minutes at the surface and 8 minutes on bottom. During the white shrimp study, 10-minute tows were made with a 1.2- by 3.0-m. (4- by 10-foot) net at the surface, at middepth, and on bottom for each series. The objectives of the studies were to determine for juvenile and subadult brown shrimp, or white shrimp, or both: (1) peaks of emigration, (2) size at which they emigrate, (3) sex ratio, (4) vertical

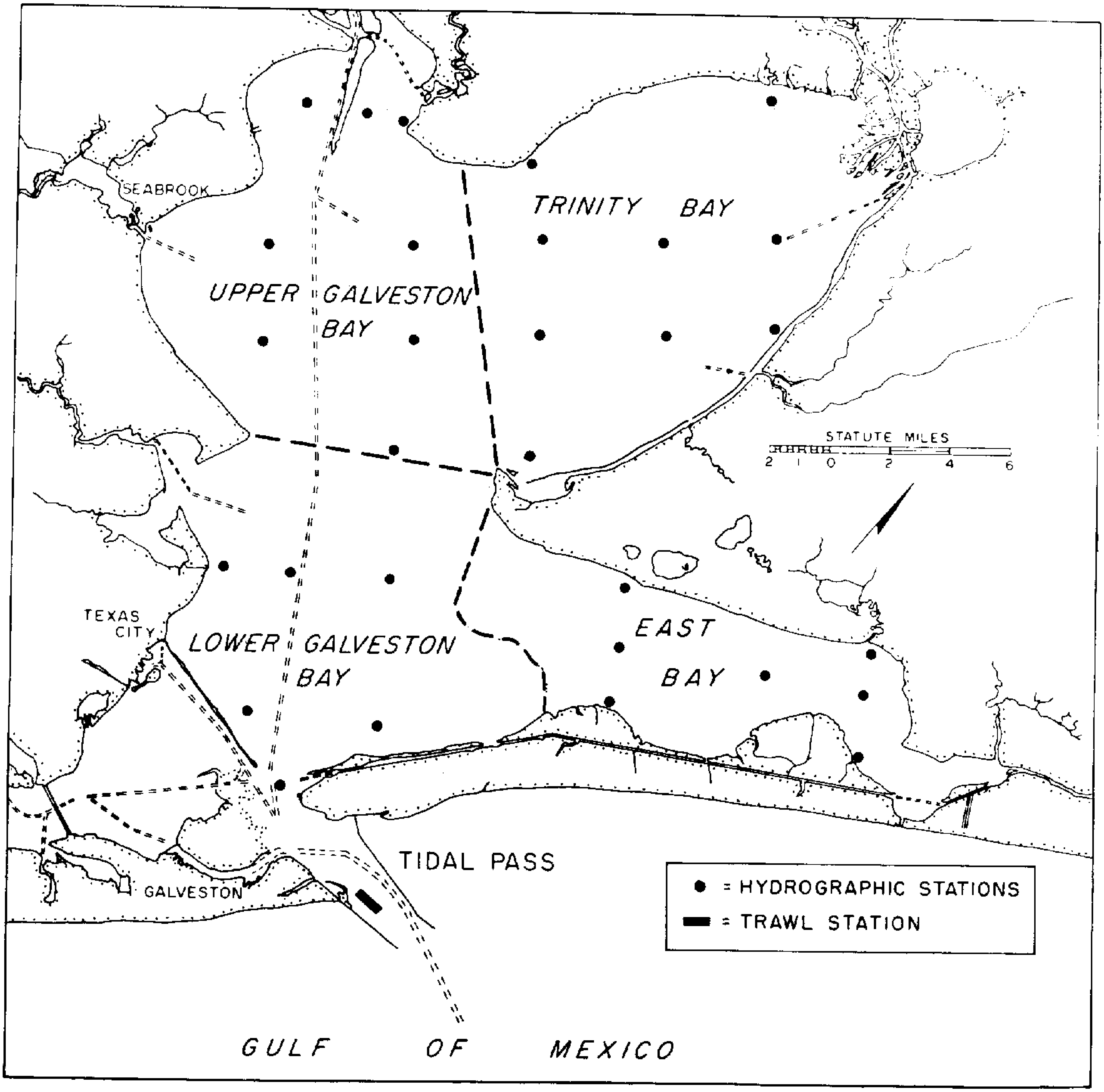

Figure 20.--Hydrographic stations in Galveston Bay and the trawl station in the Galveston tidal pass, 1966.

distribution, and (5) relations between temperature, salinity, size, and abundance.

Brown Shrimp

To estimate relative abundance of emigrating brown shrimp, we combined all shrimp caught in bottom and surface trawls during the day and night. Two peaks of emigration occurred--the first in mid-May and the second in mid-June. Because brown shrimp were leaving the bay when we began sampling, we do not know the magnitude of the first peak or when it started.

All shrimp caught in the tidal pass were combined by weekly intervals to represent the size of emigrating brown shrimp during the study. Brown shrimp caught from May 14 to 21 had a mean length of 58.0 mm. (2.3 inches). Mean length was much greater (79.7 mm.; 3.1 inches) the following week (May 22-28) and tended to increase gradually for the rest of the sampling period.

A comparison of day and night catches between surface and bottom hauls indicated that during ebb tides, emigrating brown shrimp remained close to the bottom during the day and migrated vertically to surface waters at

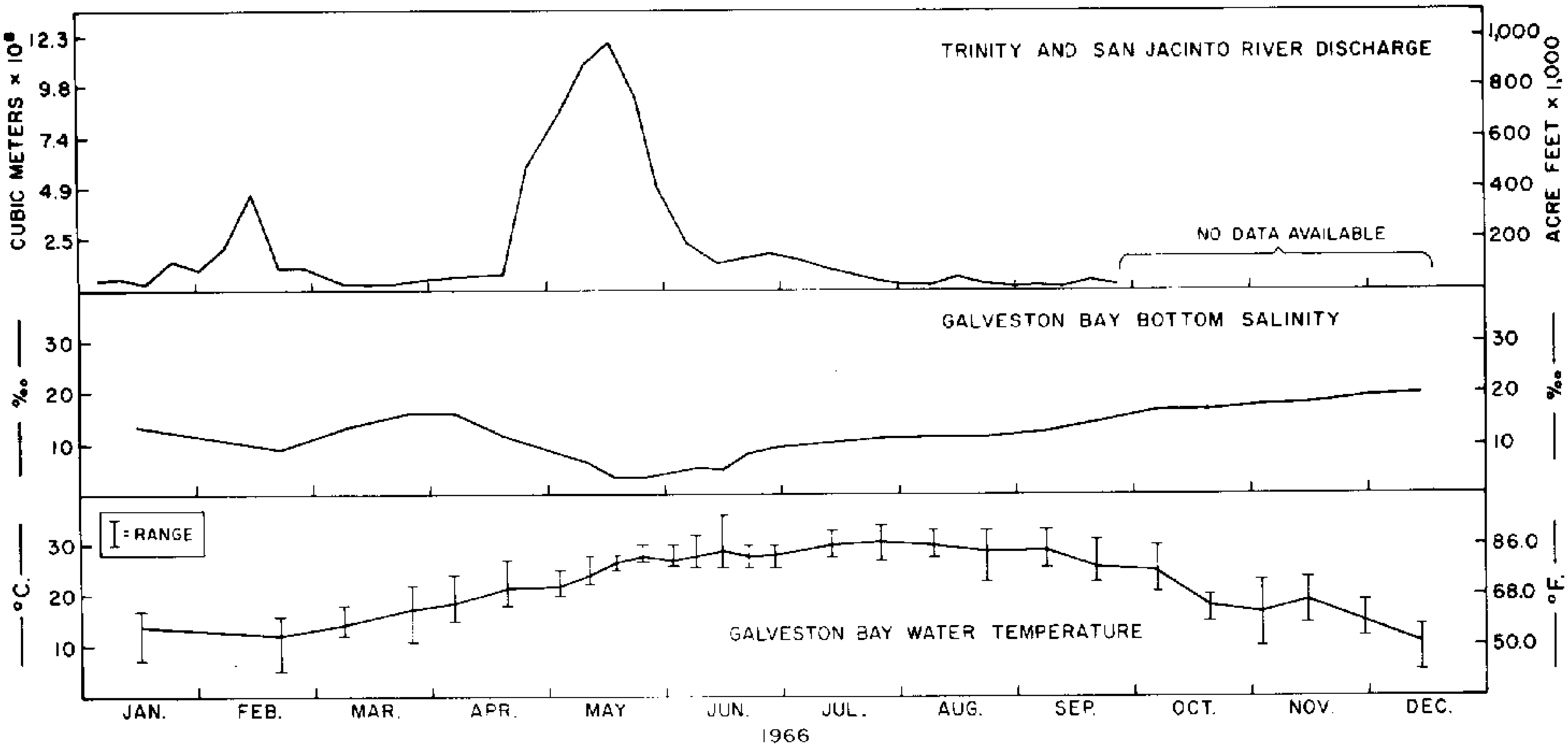

Figure 21.--Bottom water temperature (mean and range), river discharge, and salinity in Galveston Bay, 1966.

night. During the day, bottom tows averaged 0.85 shrimp per minute towed, and surface tows, 0.01; at night bottom hauls averaged 0.22 shrimp per minute and surface hauls, 1.21. Mean lengths of shrimp, regardless of time or depth, were similar.

White Shrimp

More white shrimp were caught in bottom tows than in midwater tows during the study. Large numbers of shrimp were caught in surface tows on two sampling dates, but they were absent in the surface tows during the day on all other sampling dates. Statistical tests showed that catch per unit of effort increased significantly from surface to bottom during the day. Vertical distribution at night was not determined because ebb tides usually occurred during the day in the fall and winter months.

Peaks of white shrimp emigration were correlated closely with rapidly decreasing temperatures and salinities. The first peak of emigration occurred October 19, when daily mean water temperature dropped from 24° to 19° C. (75.2° - 66.2° F.). The next three peaks of emigration also coincided with drops in temperature. For the rest of the season, however, the relation was not clear, probably because temperature changes were not as great and because emigration was more nearly constant. Emigration occurred at temperatures between 19° and 8° C. (66.2° - 46.4° F.).

The mean lengths of shrimp caught on the same date in surface, midwater, and bottom tows, and between sexes, were similar. Size at emigration decreased significantly with, and was closely related to, a decrease in water temperature. There was no obvious relation between salinity and size of emigrating shrimp.

Of 2,964 white shrimp caught in the tidal pass, 1,633 (55.1 percent) were females. The sex ratio did not deviate significantly from a 1:1 ratio.

Character for Identification of Postlarval Penaeid Shrimp

Studies of the biology of postlarval brown, pink, and white shrimp have been hampered by difficulties in differentiating between species. For postlarval shrimp 10 mm. (0.4 inch) total length or less, published descriptions, provisional keys, seasonal occurrences, and size differences have been used successfully to separate postlarvae of the brown and white shrimp entering Galveston Bay. The problem remained, however, of species differentiation among shrimp between the lengths of 10 mm. (0. 4 inch) and 25 mm. (1.0 inch).

In examining postlarvae from Galveston Bay, we noted a morphologic character by which we could distinguish brown from white shrimp at total lengths from 10 to 25 mm. (0.4 - 1.0 inch): White shrimp lack spines on the dorsal carina, whereas brown shrimp have spines on the dorsal carina of the sixth abdominal segment. This character is especially valuable in areas such as Galveston Bay where pink shrimp are rare.

On the basis of the examination of shrimp of known parentage, we determined that the number of spines on the dorsal carina cannot be used to separate postlarvae of brown and pink shrimp. The number of spines for each species generally increases with increasing size, and for shrimp of a given length, the number of spines differs little between species.

W. Lee Trent, Project Leader

EVALUATION OF ESTUARINE DATA

Estuarine Atlas

The need for an inventory of estuarine areas, such as the one being planned and coordinated by the ETCC (Estuarine Technical Coordinating Committee) of the Gulf States Marine Fisheries Commission is emphasized by competition for these coastal waters by fish and wildlife resources on one hand and industrial, commercial, residential, and agricultural interests on the other. Documentation of the biological value of estuaries for perpetuating fish and wildlife resources is needed if the integrity of our estuaries is to be maintained.

The ETCC intends to standardize field methods for collecting estuarine data and formats for recording all "atlas" data. These methods and formats are to be used by the participating States and agencies. Alabama, Mississippi, and Louisiana receive financial assistance from Public Law 88-309 funds to inventory their estuarine area; the Gulf coast of Florida will be inventoried by the Bureau of Commercial Fisheries; and Texas will participate to the extent funds and staff can be made available.

Assistance was provided an ETCC subcommittee in preparing an outline for "Area Description." It was reviewed by the full committee, and several changes were suggested. The final version, which includes a listing of priority items and standardized tables for recording data, was drafted in cooperation with the Bureau of Commercial Fisheries Biological Laboratory, St. Petersburg Beach, Fla., and adopted by the ETCC for the Estuarine Atlas.

Assistance with the review of formats for the "Biology" and "Hydrology" phases of the Atlas was also provided to the respective ETCC subcommittees. The format for "Hydrology" has been adopted by the ETCC, but the "Biology" format is being revised and the "Sedimentology" format is being drafted by their respective subcommittees.

Fish Food Study

Clear Lake, a brackish bay on the western side of Galveston Bay, has long been known as a valuable nursery area for commercially important fish and crustaceans. The area has been subjected to considerable investigation by personnel from Federal and State conservation agencies. Much of this effort, however, was restricted in scope, being limited to studies on the relative abundance and seasonal distribution of several selected species. Therefore, a study on the food of fish from Clear Lake was begun as an additional contribution to the biology of the lake.

A total of 228 samples containing 5,016 fish was collected with a small trawl from 10 locations in Clear Lake. Of the 40 species in the samples, 8 contributed 4,628 specimens and may be classified as "dominants"; the remaining 388 specimens were distributed among 32 species.

The Atlantic croaker (Micropogon undulatus) and the sand seatrout (Cynoscion arenarius) were most numerous with 2,342 and 1,041 specimens, respectively. Ninety-one percent of the croaker stomachs and 85 percent of the sand seatrout stomachs contained food.

Mysidacea, copepods, plant material, fish, organic detritus, and annelids occurred most frequently in the stomachs of croakers; mysidacea, palaemonid shrimp, and fish made up the bulk of the diet of the seatrout (table 8).

Table 8.--Percentage frequency of occurrence of different food items in stomachs of 2,131 Micropogon undulatus and Cynoscion arenarius taken from Clear Lake, Tex.

Food item	C. arenarius[1]	M. undulatus[2]
	Percent	Percent
Foraminifera	3.1	0.0
Bryozoa	T [3]	0.0
Annelids	11.8	0.3
Crustacea:		
Unidentified remains	4.0	1.8
Branchiopoda	0.5	0.0
Copepoda	52.9	4.0
Ostracoda	5.0	0.0
Cirripedia	0.3	0.0
Mysidacea	53.6	67.2
Amphipoda	9.0	2.5
Isopoda	2.3	0.4
Stomatopoda	0.2	0.1
Penaeid shrimp	1.1	4.4
Palaemonid shrimp	3.8	29.8
Crangonid shrimp	0.1	0.0
Crabs	1.2	2.0
Spiders	T [3]	0.0
Insects	2.0	0.1
Clams	0.5	0.0
Squid	T [3]	0.0
Fish	19.5	24.8
Plant debris	30.2	4.9
Unidentified organic debris	15.4	2.0
Mud and sand	8.6	1.5

1/ 23-160 mm. total length.
2/ 10-165 mm. total length.
3/ Items with less than 0.1-percent frequency occurrence.

Of lesser importance in the diet of these two species were foraminifera, bryozoa, branchiopods, ostracods, barnacles, amphipods, isopods, stomatopods, penaeid and crangonid shrimp, crabs, spiders, insects, clams, and squid.

The abundance of plant material and mud and sand in the stomachs of croakers suggests that this species forages for food in the vegetation bordering Clear Lake. On the other hand, the paucity of these items in the diet of the seatrout suggests that this species forages in more open waters.

The tabulation and analysis of food data for the dominant species will ultimately include differences in food items based on size, season, and habitat. Food of the nondominant species can be tabulated only as total percentage frequency of occurrence because so few samples are available.

Richard A. Diener, Project Leader

EXPERIMENTAL BIOLOGY PROGRAM

We continued to study the effects of temperature, salinity, light, and food on laboratory-held penaeid shrimp. This information is useful in defining natural nursery areas of various species and in predicting the effects which manmade changes may have upon these areas. Our studies of salinity and temperature requirements of commercially important penaeid shrimp will also be used to establish management techniques for pond culture.

During the year, we showed that the ability of shrimp to survive extremes of temperature and salinity depends on the size or age of the animals tested, as well as on the species. Not only are adult brown and white shrimp somewhat less tolerant of extreme conditions than are juveniles, but also postlarvae of various sizes show different tolerances. Laboratory-hatched postlarvae of brown shrimp that were 8 mm. (3/8-inch) in rostrum-telson length are less able to withstand low salinity and temperature than are 12-mm. (1/2-inch) postlarvae. Such information may be of value in determining the size of postlarvae used to stock ponds for shrimp culture.

We also noted differences in the ability of animals to regulate the concentration of their body fluids. Juveniles of white and brown shrimp appear to be better regulators of internal salt content than the adults. This is reflected in survival of animals exposed to changes in external salinity as well as in the total salt content of the blood.

Zoula P. Zein-Eldin, Acting Program Leader

SHRIMP METABOLISM

Emphasis this year was on a study of the response of individual animals to selected salinities. Previous experiments indicated that postlarval brown and white shrimp could tolerate wide ranges of salinity. We did not know, however, how salinity affected the individual animal.

To study the effects of salinity on the individual, we measured the total osmoconcentration and the chloride content of the blood of juvenile and adult shrimp taken from different environments. Samples of shrimp blood were drawn either from the heart or from the base of a walking leg (fig. 22). The former method was used for the smaller shrimp and the latter when we tested a single shrimp on several successive days.

To date, we have tested blood samples from 80 brown shrimp (85-210 mm. total length; 3.3-8.3 inches), 65 white shrimp (80-140 mm.; 3.1-5.5 inches), and 27 pink shrimp (145-180 mm.; 5.7-7.1 inches). Brown shrimp were exposed either in nature or by acclimation in the laboratory to salinities ranging from 13 to 35 p.p.t. White shrimp tested had been exposed to a broader range of salinity; some specimens were obtained from the fresh water of the Trinity River estuary and others had been reared in our Laboratory and gradually acclimated to 54 p.p.t. Adult pink shrimp tested had been exposed to salinities ranging from 17 to 42 p.p.t.

Neither the brown nor the pink shrimp tested have been able to regulate blood salt concentration at low salinity as efficiently as white shrimp. Furthermore, adult pink shrimp are less able to withstand lowered salinity than are adult brown shrimp. These differences may be associated with the occurrence of the species in nature. White shrimp are often taken in waters of low salinity, but juvenile and adult brown shrimp are uncommon in such waters.

Adult brown shrimp were acclimated to specific salinities at two temperatures--25° and 18° C. (77° and 63° F.)--to see whether temperature influences the ability of the animals to regulate the salt content of the body fluids. Animals at the lower temperature did not appear to regulate as well as animals held at 25° C. Similarly, postlarval brown shrimp were less able to survive salinity changes at low temperatures than at high temperatures.

An additional study was made this year to determine the energy source used by the penaeids. Determinations of total blood-reducing substances and of blood glucose indicated that only traces of sugar were present in the blood of adult pink and brown shrimp. The absence of available energy sources in

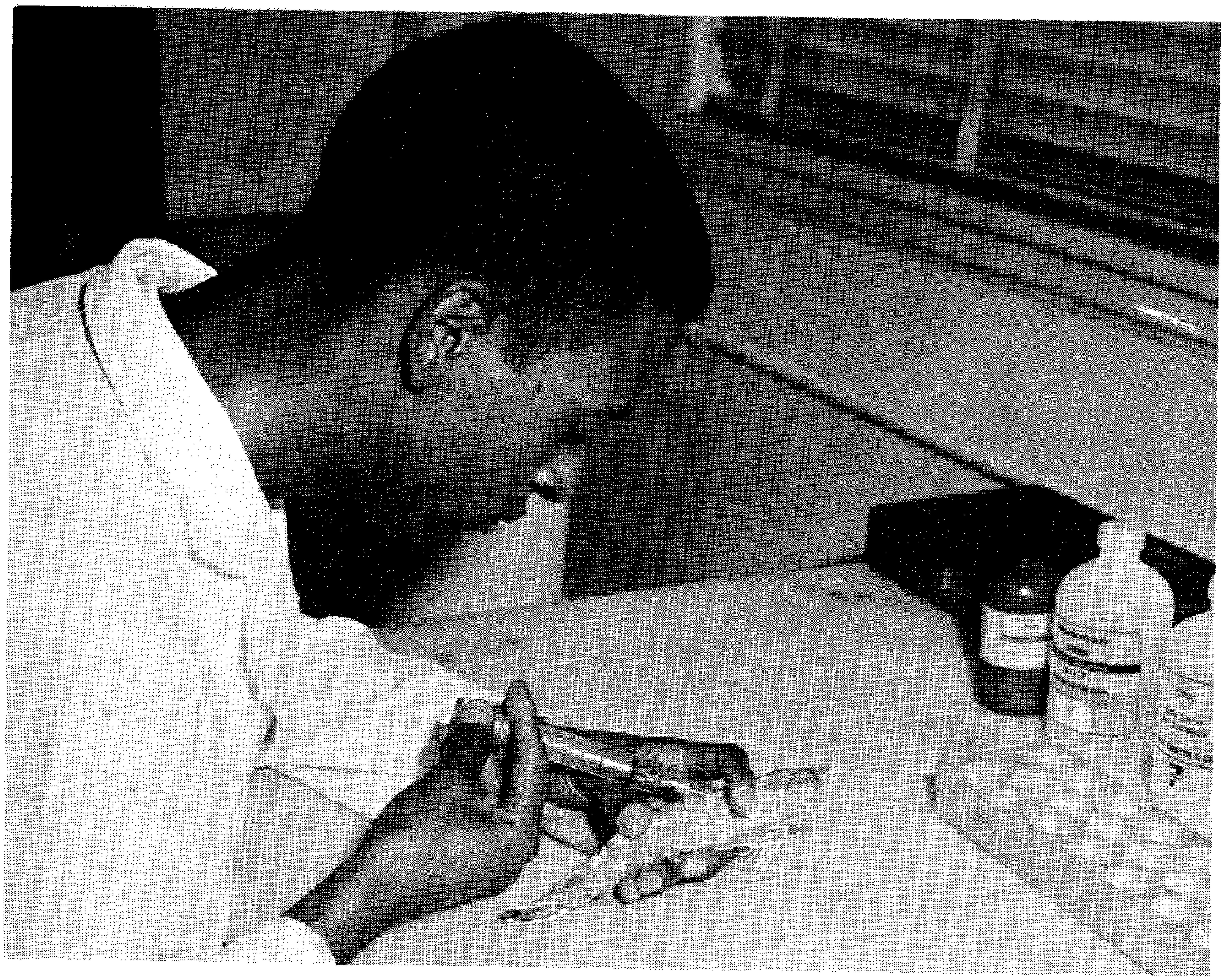

Figure 22.--Technician drawing blood from shrimp heart.

the blood may indicate a requirement for continuous feeding to supply energy.

Zoula P. Zein-Eldin, Project Leader

GROWTH AND SURVIVAL OF ESTUARINE-MARINE ORGANISMS

This project is concerned primarily with determining the short-term tolerances of postlarval penaeid shrimp to salinity and temperature, and the optimum conditions for shrimp growth. During the year, we studied the survival of postlarval white and brown shrimp exposed to selected combinations of temperature and salinity, and completed growth experiments with two species of laboratory-hatched shrimp. Studies also were made to determine the effect of container size on growth and survival of postlarval brown shrimp.

Survival

Three 24-hour experiments were made to define the 80-percent survival limit of postlarval white shrimp. Test temperatures ranged from 7.5° C. (46° F.) through 37.5° C. (99° F.), and salinities ranged from 2 through 45 p.p.t. Combinations of salinity and temperature resulting in 80-percent survival are shown in table 9.

We compared results of these experiments with results of past experiments with brown shrimp. Postlarval white shrimp withstood higher temperatures and lower salinities than postlarval brown shrimp. Conversely, young brown shrimp withstood lower temperatures than did white shrimp. Most postlarval white shrimp enter the estuaries later in the year than brown shrimp and are normally subjected to warmer water. In the Galveston area, juvenile white shrimp frequently penetrate the

Table 9.--Percentage survival of postlarval white shrimp at various combinations of temperature and salinity

Temp.	Salinity								Temp.
	2	5	10	15	25	35	40	45	
° C.	P.p.t.								° F.
7.5	-	-	0	0	-	0	-	-	46
10.0	-	-	-	*	*	-	-	0	50
12.5	-	-	-	*	*	-	-	-	55
15.0	-	-	*	0	*	-	-	-	59
25.0	-	*	*	0	*	0	-	-	77
32.5	*	*	*	0	*	0	-	-	91
35.0	-	-	*	0	*	-	-	-	95
37.5	-	-	0	0	-	0	-	-	99

* = survival of 80 percent or more.
- = survival less than 80 percent
0 = conditions not tested.

estuary to water of lower salinity than that entered by brown shrimp.

Results of previous experiments suggested a shift in salinity and temperature tolerance during the early postlarval life of brown shrimp. We designed a study to investigate this hypothesis by using laboratory-hatched postlarval brown shrimp. Tests were made at weekly intervals for 3 weeks to determine the 80-percent survival limits. Results indicated that as postlarval shrimp became larger (or older) they survived a wider range of salinities.

Growth

We conducted 30-day growth experiments with two groups of laboratory-hatched postlarvae. The first study was made with white shrimp held at temperatures of 15° C. (59° F.), 18° C. (65° F.), 25° C. (77° F.), and 33° C. (91° F.) at selected salinities. As with animals collected in nature, animals grew faster at the higher water temperatures. Survival was poorest at 15° C. (59° F.); most shrimp died before the end of the experiment.

In the second experiment, laboratory-hatched brown shrimp were held at 11° C. (52° F.), 18° C. (65° F.), 25° C. (77° F.), and 32° C. (89° F.) at various salinities. Best growth occurred at 32° C. (89° F.). At 11° C. (52° F.), all animals were dead within 12 days. Shrimp survived best at 25° C. (77° F.) at all salinities except 2 p.p.t., the lowest salinity tested. Survival at 2 p.p.t. was poorer than in previous experiments. This possibly is explained by the small initial size of the postlarvae (6 mm. total length; 1/4 inch) as compared with 8- to 12-mm. (3/8- to 1/2-inch) shrimp collected from the surf for previous experiments.

Effect of Container Size

One experiment was made to determine the effect of container size (volume and surface area) on growth and survival of postlarval brown shrimp. We kept 100 shrimp in each of five containers of different dimensions for 1 month. Water volume and dimensions of the containers are given in table 10. At the end of the month, all animals were weighed and measured. There was no difference in average size of the animals from four tanks with volumes of 22 to 44 liters, but the animals in the 4-liter tank were significantly smaller than any of the others. Survival in all containers was above 80 percent.

George W. Griffith, Project Leader

Table 10.--Dimensions and volume of experimental containers

Tank number	Length		Width		Water depth		Volume	
	Inch	Cm.	Inch	Cm.	Inch	Cm.	Gal.	Liters
1 (Control)	30	76.2	12	30.5	7	17.8	10.9	44
2	30	76.2	12	30.5	3	7.6	5.4	22
3	20	50.8	10	25.4	6	15.2	5.4	22
4	12	30.5	8	20.3	14	35.6	5.4	22
5	11	27.9	7	17.8	2.6	6.6	1.0	4

GULF OCEANOGRAPHY PROGRAM

The Gulf Oceanography Program was conceived in late 1965 and is concerned with determining the physical factors significant to shrimp in the natural environment of the Continental Shelf and slope and the atmospheric and oceanographic processes that influence that environment. We need to examine the short- and long-term changes of the water environment over the shelf, and the relation of these variations to the general dynamics of the Gulf and to the atmospheric conditions throughout the Gulf. Further, the sedimentary environment on the shelf and slope must be defined and related to the prevailing water conditions and the biological environment. The essence of our effort is to evolve techniques that allow us to forecast the state of the environment.

The field program became effective near the beginning of the fiscal year when the R/V Geronimo was transferred to the BCF Laboratory in Galveston. During the year the vessel completed three sedimentary surveys of the shelf and three hydrographic cruises, including one of the entire Gulf of Mexico and one cooperative cruise with Texas A&M University. In addition, a detailed study of the sediments within the shrimp grounds off Galveston was started. Bottom sediments on this study were collected at stations less than 1 nautical mile apart with a chartered shrimp boat, Gus III.

Although our major effort has been devoted to the collection of data, three papers have been published on preliminary work completed during three of the cruises. Also completed was a new map (fig. 23) of the Gulf of Mexico in a conformal Lambert conic projection with the depth contours in meters. Navigational aids are now generally lacking in the western Gulf, but after Loran stations are installed in this area, we plan to update the chart frequently from soundings obtained by the R/V Geronimo.

After completion of the cruise for ground support for the Gemini XII manned space flight, the Naval Oceanographic Office assigned two contracts to this program: one to evaluate space photography and its application to fisheries and one to conduct a cruise in support of the first manned Apollo space flight.

John R. Grady, Acting Program Leader

RECONNAISSANCE SURVEY

Benthic and hydrographic samples were collected during two cruises of the R/V Geronimo to the west Florida shelf. Samples were taken as far north as Cape San Blas along transects which were about 93 km. (50 nautical miles) apart, except around the Dry Tortugas, where the effort was more concentrated. A total of 416 benthic samples were taken, and 33 hydrographic stations were occupied across the Continental Shelf and slope. The stations were distributed over the continental terrace to tie together areas that have been studied in detail with unworked areas.

Van Veen and orange peel grabs were used to obtain sediment samples on the Continental Shelf; a short coring tube was used over the slope and abyssal plain. These samples have been processed, and the textural and statistical properties computed. Results are being plotted on newly prepared charts of the area.

On the southern, west Florida shelf, the limestone bottom is covered by a thin veneer of unconsolidated sediments which are chiefly of calcareous organic origin. Distribution and composition vary from zones of quartz-shell sand, roughly paralleling the coast, to an almost completely foraminiferal sand on the outer edge of the shelf and down the slope. Off the northern shelf, south of the Florida panhandle, the inshore zone of the detrital component is considerably more extensive than on the southern shelf. The organic origin of the sediments, particularly on the southern slope and shelf, appears to be the dominant factor controlling the size distribution of particles.

Fossil assemblages were dredged from the slope during the cruises to Florida waters. We believe that these ancient forms mark old strand lines formed during the Pleistocene when sea levels were lower than at present.

A cooperative cruise with Texas A&M University was made in December along the 183-m. (100-fathom) isobath off the Mexican coast south of the Rio Grande. The objectives of this cruise were: (1) to determine if any residual effects of Hurricane Inez were evident in the waters over which it passed; (2) to obtain bottom sediments along three transects for study and comparison with material previously collected elsewhere in the Gulf; and (3) to locate and verify a large-scale feature, about 28 by 56 km. (15 by 30 nautical miles) in dimension, shown on navigation charts as an eastward projection of the Continental Shelf near Tampico, Mexico.

All objectives of the December cruise were fulfilled. Analysis of temperature, salinity, dissolved oxygen, and productivity data taken at depths across the track of Hurricane Inez showed so residual effects of the storm. Short cores of sediment were obtained at 14 stations on a 138.7-km. (75-nautical mile) traverse off Tecoluta and at 11 stations on a 101.7-km. (55-nautical mile) traverse off Punta Peñon. Echo soundings along the transects revealed rugged ridge and trough topography with the axis about parallel to the coast. In addition, although a number of echo sounding tracks were completed off Tampico, no projection of the Continental Shelf was observed. We consider it probably nonexistent, or mislocated on navigation charts.

During the year, 2,473 water samples were collected at depth on hydrographic surveys made to coastal waters south of Louisiana, Mississippi, and Alabama in November for "ground-truth" support of the Gemini XII manned space flight and throughout the Gulf of Mexico, including the Bay of Campeche and the Yucatan Straits. The dissolved oxygen content of these samples was determined aboard ship and frozen samples of the water were brought to our laboratory for analyses of the nutrient salts. Determinations of the phosphate-phosphorus and slicate-silicon content of these samples are nearing completion.

The final cruise of the year in June was made to survey a large canyon crossing the outer slope about 333 km. (180 nautical miles) south of Galveston. Short cores were taken along the axis of the canyon. Exploration of the canyon complex was prompted by a need for a hydrographically acceptable area for waste disposal near Galveston. Echo sounding tracks taken in this area will be used to update the conic projection of the Gulf of Mexico prepared at this Laboratory.

John R. Grady, Project Leader

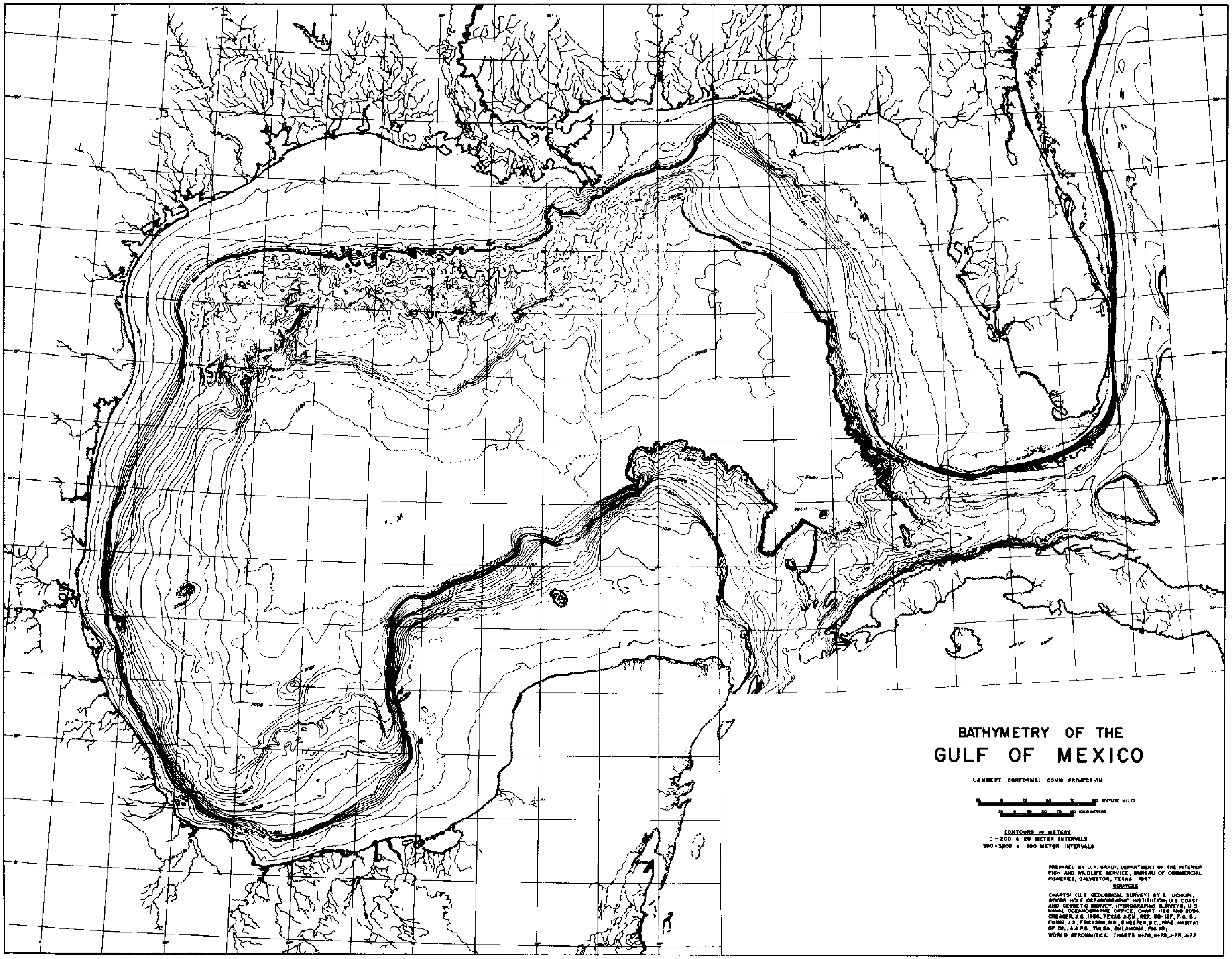

Figure 23.--Bathymetry of the Gulf of Mexico (contours are in meters).

ENERGY BUDGET AND CIRCULATION DYNAMICS

Sea-Air Interaction Study

During the year, data from a laboratory study were analyzed to describe rates of evaporation and sensible heat exchange across an air-water interface. The objectives were to measure certain features expected to exist in the few centimeters on either side of the interface, to correlate these features with the physics of air-water interaction, and to derive a method for determining the rates of evaporation and sensible heat exchange. The features of interest were: (1) an evaporatively cooled layer of surface water, (2) temperature inversions in the lowest few centimeters of air, and (3) an intense moisture gradient in the lowest layer of air.

Characteristics of the temperature inversions are apparently related to the configuration of the associated moisture profiles. Because the inversions seem to be associated with alternate layers of evaporation and condensation in the air, they also must indicate the exchange rates of heat and moisture between the air and water. With increasing air-water temperature differences, the exchange rates seemingly do not increase linearly as predicted by equations, but rather stepwise. These "steps" are apparently associated with the necessity for a more efficient vertical flux of heat and moisture.

Level-of-No-Motion Study

Determination of relative ocean currents by geostrophic computations of serial hydrographic station data is a basic tool in oceanography. Converting the "relative" currents to "absolute" values is accomplished by defining a "level-of-no-motion"; no acceptable technique, however, has been devised for defining the no-motion level. During the year, a method for determining this level was devised and is being examined by using data gathered in the Gulf of Mexico. If this technique proves correct, our ability to describe the ocean current structure will be greatly improved.

Reed S. Armstrong, Project Leader

TRENDS IN OCEANIC CONDITIONS

A study to describe the physical properties of water of the Gulf of Mexico was begun during the year with three cruises (9th, 10th, and 12th) of the R/V Geronimo.

One of the activities of the ninth cruise was a hydrographic survey of the upper 300 m. (164 fathoms) of water over the slope of the Continental Shelf off Florida in the Gulf of Mexico. Twenty hydrographic stations were occupied between June 30 and July 13, 1966. During August 4-18, about a month later, the R/V Alaminos (Texas A&M Research vessel) made hydrographic observations during a cruise in the eastern Gulf. A comparison of the data from the two cruises indicated the presence of two clockwise-rotating gyres superimposed on the mean flow. One gyre was in the northern portion, and the other in the southeastern sector of the eastern Gulf. Both gyres were still present in February-March 1967 during cruise 12 of the R/V Geronimo.

The gyres had changed in position and configuration during the month between cruise 9 and that of the R/V Alaminos. These results were interpreted to mean that ocean circulations are not steady and that the characteristics of water masses might change over rather short time periods.

Cruise 10 of the R/V Geronimo was made November 8-17 to obtain data on the waters around the Mississippi River Delta. The primary purpose of the operation was to establish "ground truth" for the photographs taken from the Gemini XII manned space flight. The station plan of the cruise was organized to exhibit the scale of oceanic features observable from satellite photographs. Although cloudiness prevented photographing the surveyed area, the cruise was successful in obtaining detailed information on this sparsely sampled area.

Data on temperature, salinity, dissolved oxygen, and inorganic nutrients were collected from 79 hydrographic stations during cruise 10. Analysis of these data revealed that the water from the Mississippi River was not discharged in any regular pattern, but moved seaward in three different forms: (1) flows that hugged the coastline, (2) tongues that penetrated directly seaward, and (3) a tongue that extended into a well-defined, semipermanent, cyclonic eddy to the east of the delta (fig. 24).

Although the Mississippi River is the largest river emptying into the Gulf of Mexico, the discharge from the river (salinities less than 34 p.p.t.) generally was kept within 55 km. (30 nautical miles) of the coast. The large eddy to the east of the delta apparently resulted from the low-salinity river water being drawn seaward by an offshore, northeasterly current.

Cruise 12 of the R/V Geronimo (February 20 to April 1, 1967) was the first of an expected series of hydrographic surveys of all the waters of the Gulf. Repeated problems with the ship's navigational gear required that the operations be curtailed in the eastern Gulf, but the cruise plan was rearranged so that a survey of the entire Gulf could be made. During this cruise, 114 hydrographic stations were occupied and 281 bathythermograph casts were made. Vertical plankton hauls to 100-m. (55-fathom) depth at each hydrographic station and a number of vertical hauls to near the bottom in the basins of the Gulf were planned, but

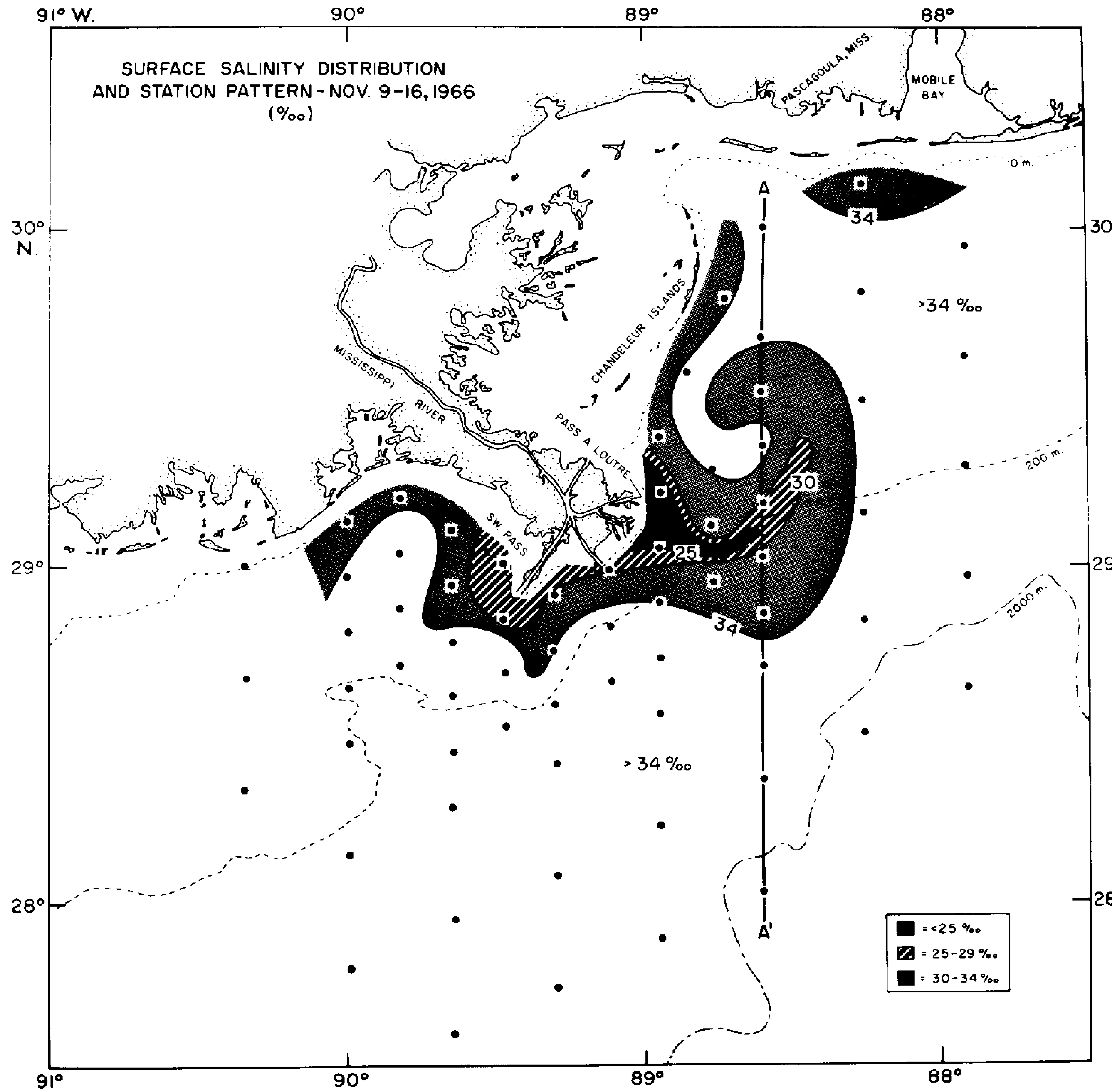

Figure 24.--The surface salinity distribution around the Mississippi Delta, November 9-16, 1966. Note the eddy northeast of the delta.

because of almost continuously poor weather, only 87 shallow and 2 deep plankton hauls were completed.

The distribution of surface temperature and circulation, as inferred from the surface density distribution, are presented in figure 25. Warm water (more than 24° C.; 75.2° F.) from the Caribbean Sea enters the Gulf along the western side of the Yucatan Straits and moves north to about lat. 28° N. This flow then turns sharply to the south, and after following a rather irregular path, leaves the Gulf through the Florida Straits. These currents are the main driving force for the circulation throughout most of the Gulf.

Some of the Caribbean water entering the Gulf returns as countercurrents, in a series of eddies, on the west of the Yucatan Straits. Other Caribbean water encounters an apparent countercurrent from the Florida Straits off the coast of Cuba, thereby setting up a clockwise-rotating eddy defined by the "C"-shaped cell of water warmer than 26° C. (78.8° F.). The flow from the western edge of this eddy to about the center of the Yucatan Straits is south, toward the Caribbean. The

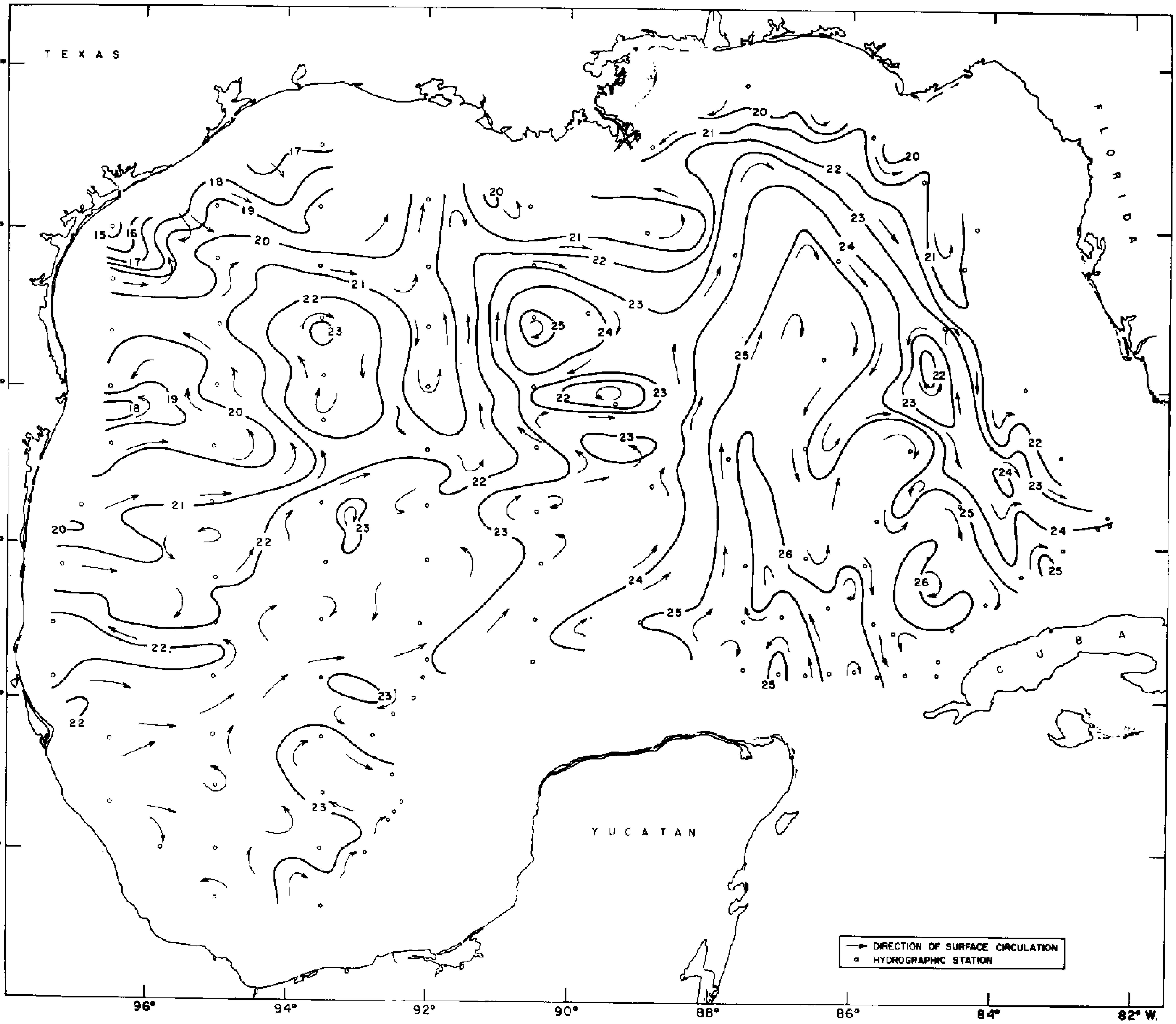

Figure 25.--Surface temperature distribution (°C.) and the pattern of the surface circulation from cruise 12 of the R/V Geronimo (February to April 1967).

remaining water entering the Gulf seemingly moves westward across the Campeche shelf and then turns northeastward to join the main flow.

The circulation of the eastern Gulf of Mexico reacts directly to the looping flow that enters through the Yucatan Straits and departs through the Florida Straits. Interaction of this loop current with adjacent waters establishes the circulation over most of the western Gulf. The general easterly and northeasterly flow in the western Gulf is probably also associated with the prevailing south and southeast winds over the area. The small pockets of cool water near shore may originate from river discharge and land runoff.

From the surface information compiled from the 12th cruise, three features of particular significance were noted: (1) the presence of a southward flowing countercurrent through the Yucatan Straits; (2) the lack of offshore penetration of Mississippi River discharge; and (3) the turbulent characteristic of oceanic circulations, as evidenced by the numerous eddies present, especially those bounding the main flow of the loop current.

Reed S. Armstrong, Project Leader

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